ASTRONOMY

June 1980
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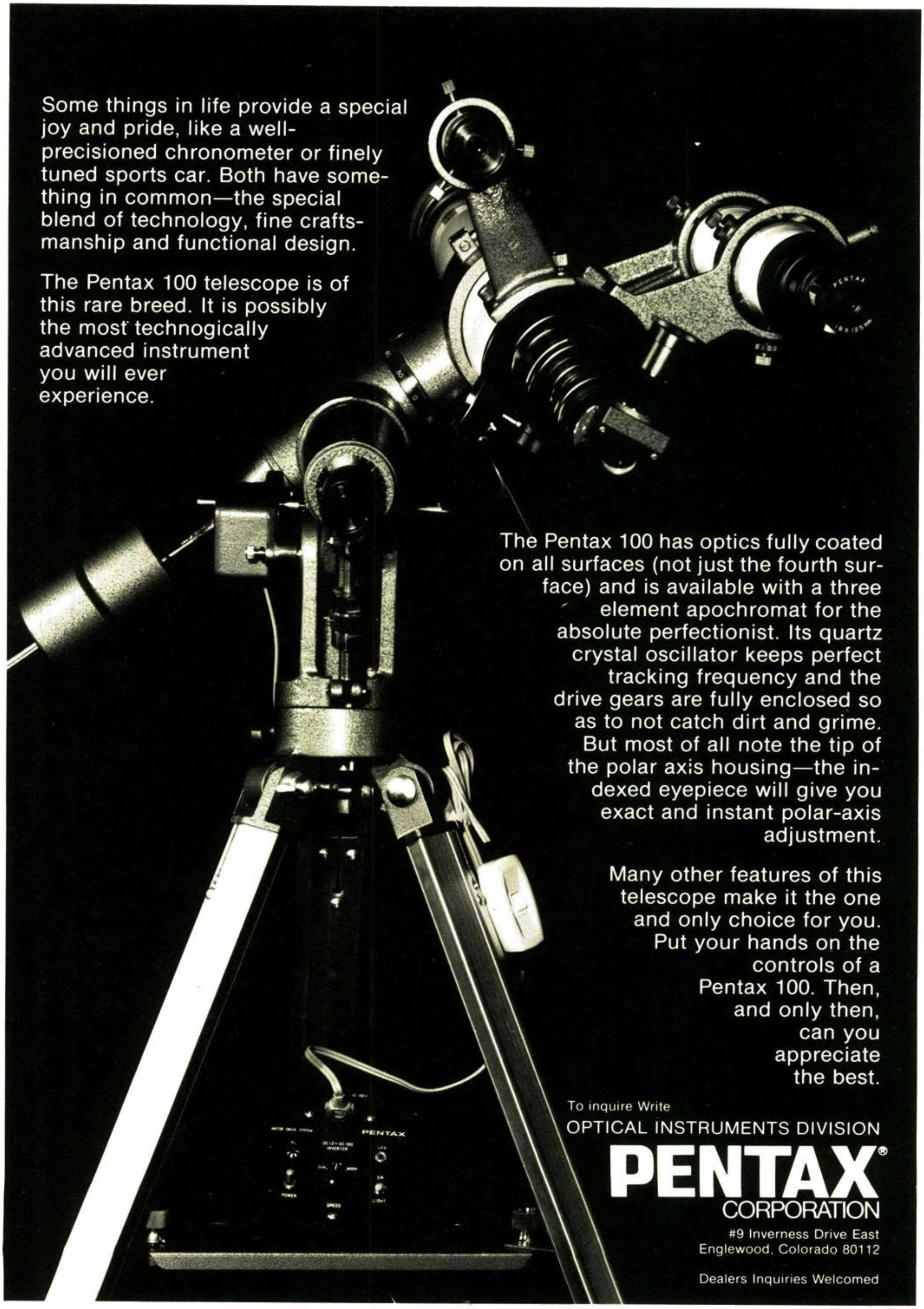
Cosmic Contamination

KAO: Mission Incredible

How to Build a Dobsonian Telescope

Eclipse over Kenya



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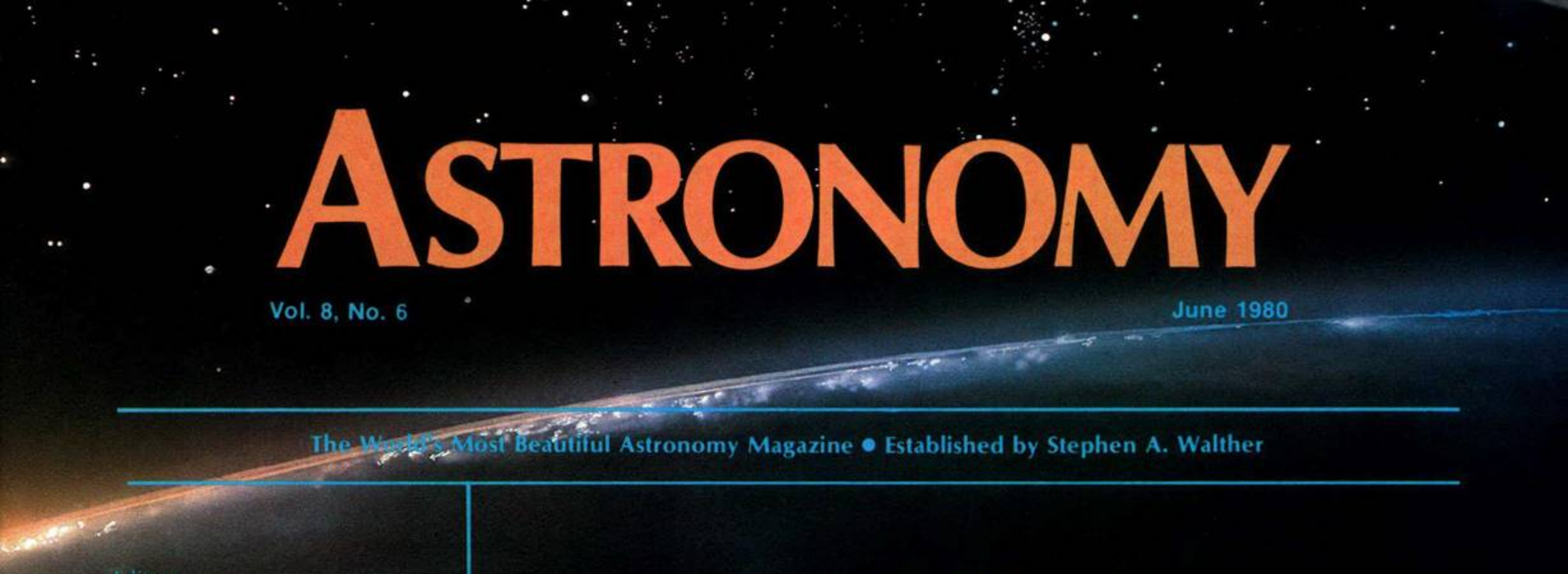

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Cover: **"Solar eclipse —**
Shadow of the moon;
Veiled Venus attends
The diamond in the sky."

Photograph and poem by Angel Thompson, Taita Hills, Kenya. This page: Our feature story begins in 1969, when a meteoroid entered Earth's atmosphere and fell on the Mexican village of Pueblito de Allende....Painting by Mark Paternostro.

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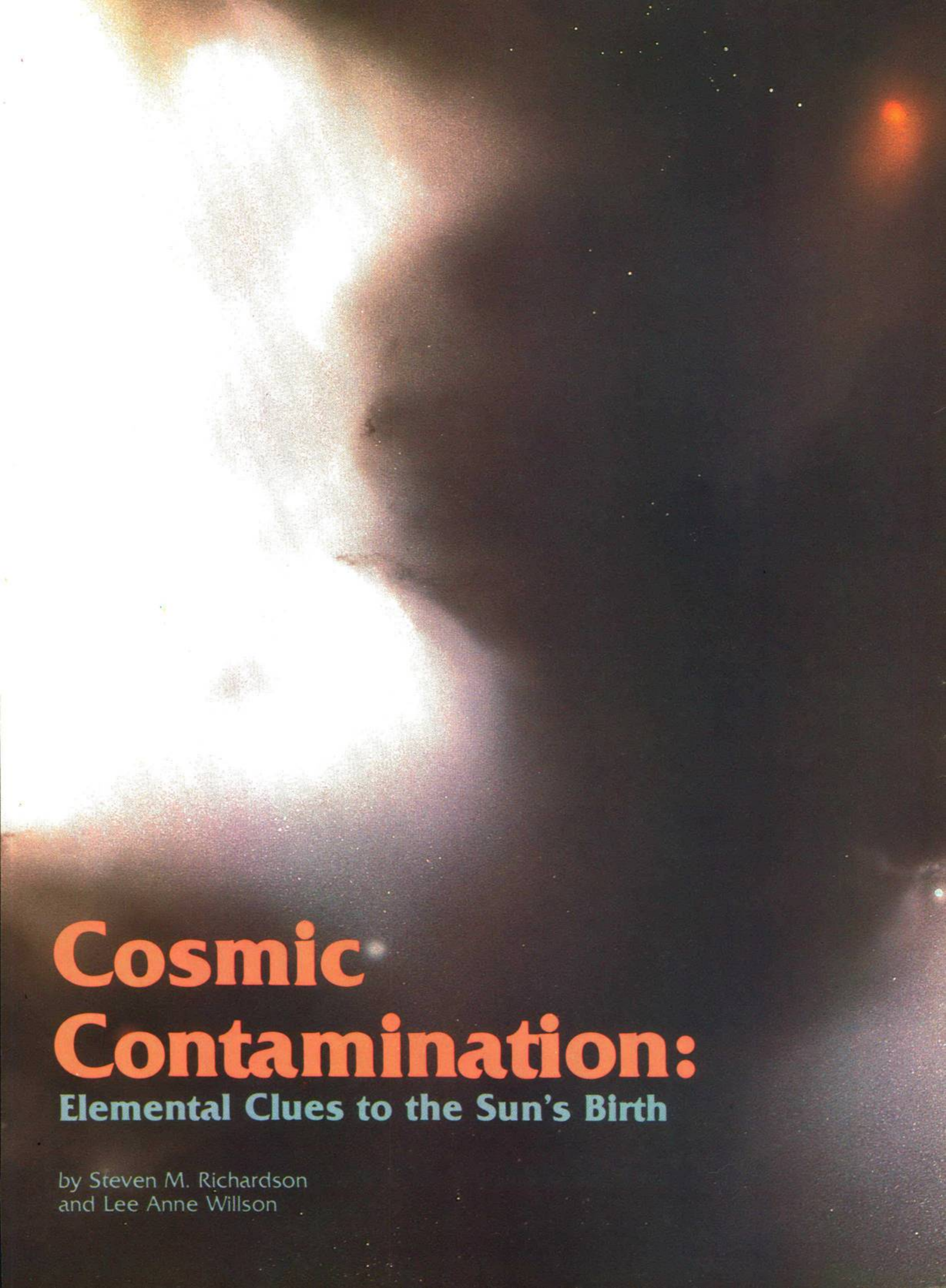
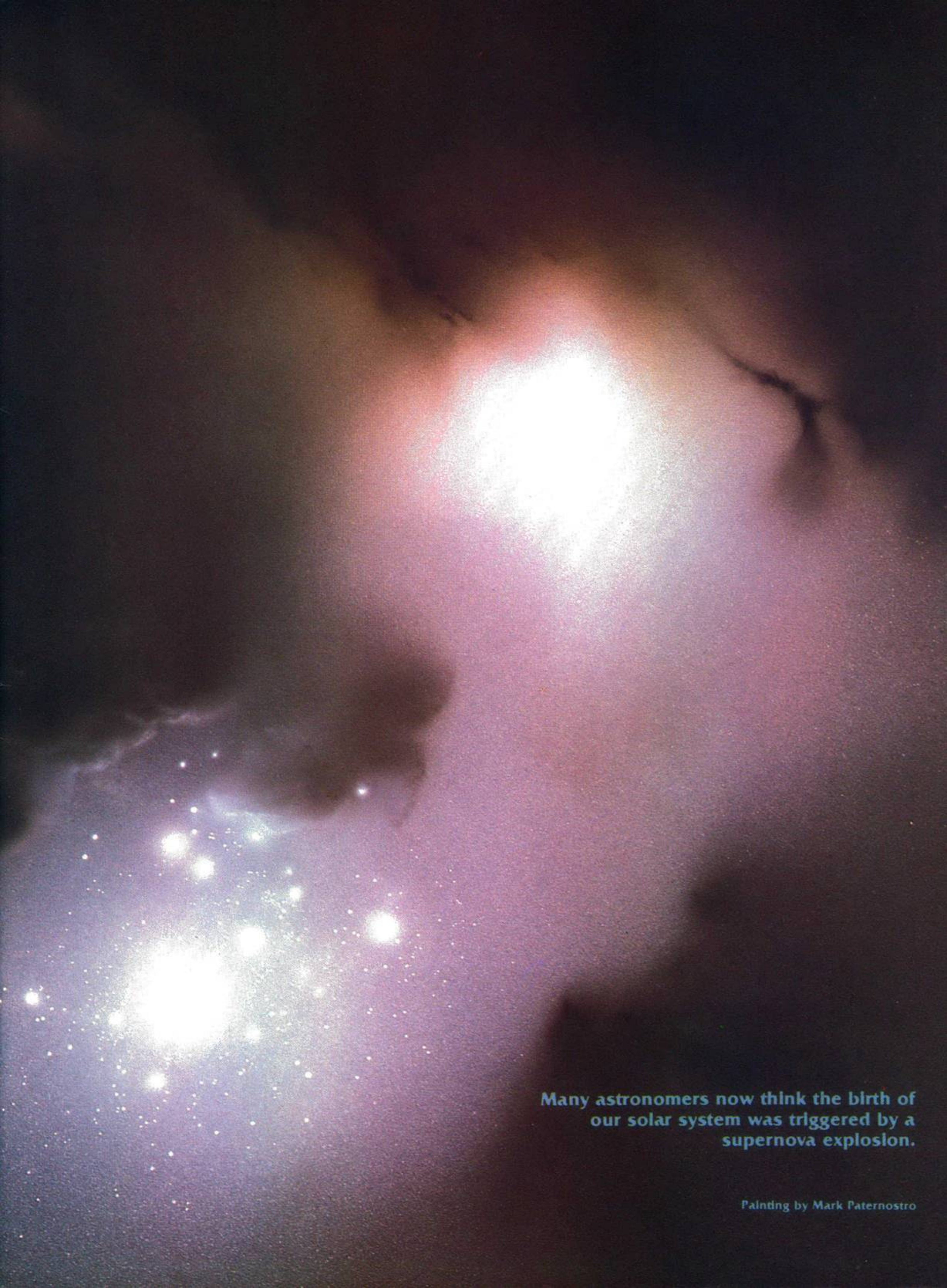


Cosmic Contamination:

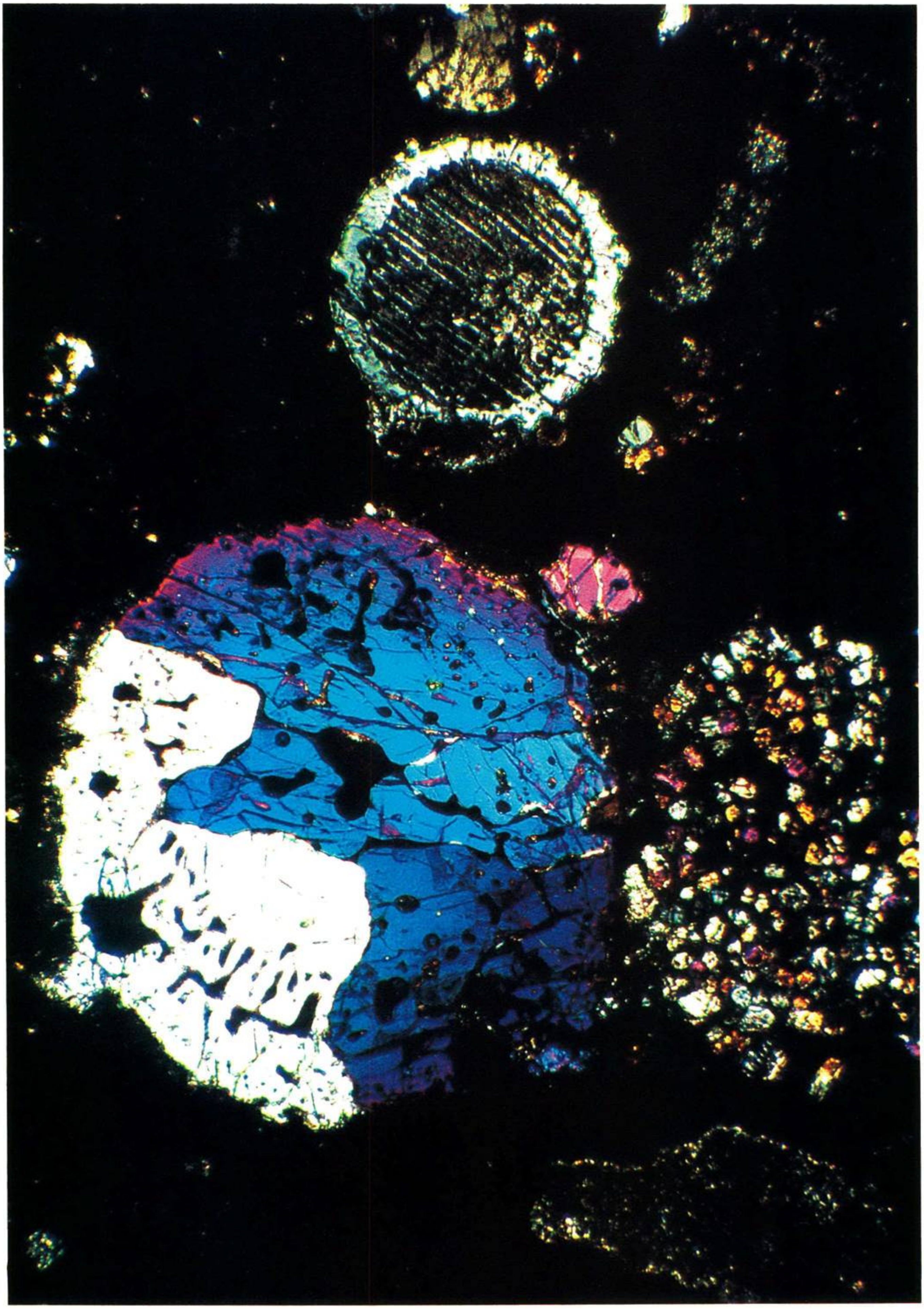
Elemental Clues to the Sun's Birth

by Steven M. Richardson
and Lee Anne Willson



Many astronomers now think the birth of our solar system was triggered by a supernova explosion.

Painting by Mark Paternostro



In the spring of 1969 a large meteorite fell near the village of Pueblito de Allende in Mexico, scattering more than a ton of material across the countryside. Cosmochemists, poised to study the subtle chemical nature of the first lunar samples soon to be returned aboard Apollo 11 later that year, jumped eagerly for samples of this fresh new meteorite. Of the many results that came out of the studies of this cosmic treasure, one in particular startled the scientific community.

It was the report of three scientists from the University of Chicago, Robert Clayton, Toshiko Mayeda, and Lawrence Grossman. They had measured the oxygen isotope abundances in the Allende meteorite and found that they didn't follow the pattern that had always been observed in terrestrial samples.

The arguments were complex, the physics and chemistry baffling, but the conclusion was astounding: The Allende meteorite contained material that could not have been produced by fractionation processes acting on any material similar to that found on the Earth or the Moon.

But what that meant was far more astounding: Allende was contaminated with the debris of a supernova explosion; an explosion may have triggered the very formation of the solar system itself.

Now it triggered a revolution in astronomers' thinking. And the evidence had come from studies that seldom received any attention in "traditional" astronomy — the distribution of the isotopes of the chemical elements in earth rocks, moon rocks, and meteorites — evidence that had been accumulating slowly for over three decades.

The chemical properties of an element are determined by the number of electrons that swarm about its nucleus. In a normal atom, the number of electrons that orbit the nucleus is equal to the number of protons in the nucleus. We usually say that the number of protons determines the element: 26 protons for iron, 1 for hydrogen, 8 protons for oxygen, 16 for sulfur, 79 for gold, and so forth. The nucleus contains, besides protons, other particles called neutrons. There are roughly the same number (or a few more) of neutrons as protons in a nucleus.

Protons and neutrons have about the same mass, but the electrons have very little mass — about 1/1800 the mass of a proton or neutron. The mass of the atom is therefore determined by the sum of the masses of the protons and the neutrons. The electrons are usually ignored.

The mass of atoms of any one chemical element can differ because the nuclei may contain extra or fewer neutrons. The atoms of different masses are called *isotopes*. Most elements, in fact, have several naturally occurring isotopes, some stable and some unstable. Iron has four stable isotopes; thus an atom of iron — which always has 26 protons — may have a mass of 54, 56, 57, or 58 atomic mass units (amu) depending on whether it has 28, 30, 31 or 32 neutrons in its nucleus. Of the iron occurring naturally, 92% is the isotope ^{56}Fe (26 protons and 30 neutrons) with a total mass of 56 amu.

A 100-times-magnified portion of the Allende meteorite photographed through a microscope with polarized light shows minerals in bright colors. The largest of the roughly circular objects, called chondrules, is about 1/16th of an inch across. Chondrules are very common in the most ordinary kind of stony meteorites, which are called chondrites. There is little agreement among cosmochemists about how they were formed. Photograph courtesy of Steven Richardson.

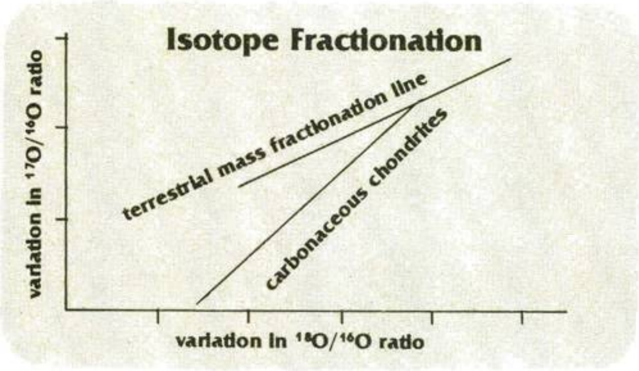
The rock that began the revolution: the Allende meteorite.

Iron also has several *unstable* isotopes, including ^{55}Fe, with 26 protons and 29 neutrons. It is radioactive; an atom of ^{55}Fe decays, ejecting several atomic particles, after an average lifetime of 2.7 years, to become an atom of manganese with 25 protons, 30 neutrons, and 25 electrons. Unstable isotopes can thus decay to become other elements.

The most common isotope of oxygen is ^{16}O; it contains 8 protons and 8 neutrons, for a mass of 16. Another stable isotope of oxygen is ^{18}O, with 8 protons and 10 neutrons. Oxygen has in fact three stable isotopes: Of the oxygen in air, water (H_2O), or terrestrial rocks, 99.759% is ^{16}O, 0.037% is ^{17}O, and 0.204% is ^{18}O. Oxygen has no naturally occurring unstable isotopes.

Because the different isotopes of a given element have the same number of electrons, they share the same chemical properties. It is therefore very difficult to separate a mixture of isotopes. However, there are a few natural processes which do result in partial isotope separation, or *fractionation*. These processes all follow a well-defined rule: The change in isotope ratio is both small and proportional to the difference in the masses of the isotope. Thus any process that enhances the ratio of ^{17}O to ^{16}O by a small amount (one unit) will enhance the ratio of ^{18}O to ^{16}O by twice that amount (two units).

All of the samples from the Earth and the Moon that have been analyzed have oxygen isotope ratios falling on the "terrestrial mass fractionation line"; that is, they follow the rule that says ^{18}O must be twice as enhanced as ^{17}O. Theorists conclude from this that the Earth and Moon were formed from material of uniform isotopic composition, and that at most a small amount of physical or chemical sorting of the isotopes of oxygen by mass has occurred during or



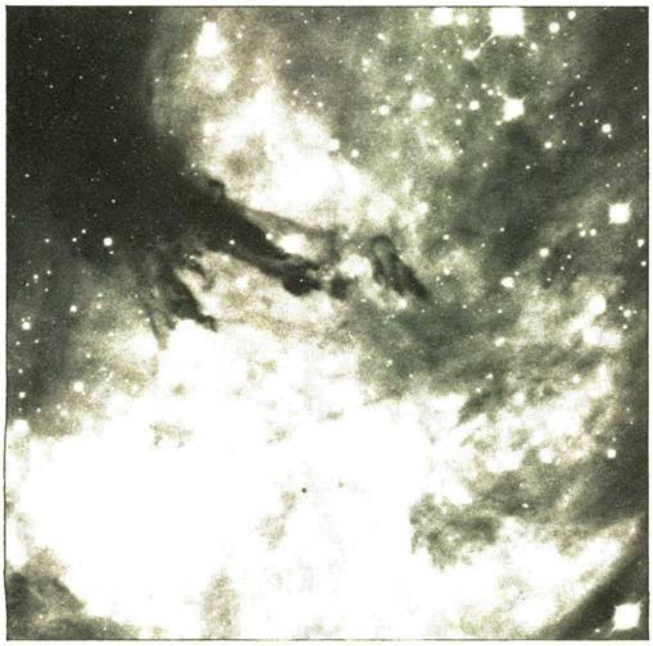
after the formation of the system.

The very small amount of chemical and physical sorting of oxygen isotopes that does take place has provided geologists with a powerful tool for determining temperatures in the past. The three stable oxygen isotopes can be exchanged for one another during the chemical reactions that form ore deposits, lavas, or even sea shells on the ocean floor. The exact proportions of ^{16}O, ^{17}O, and ^{18}O that end up in one mineral or another during these reactions lie, of course, somewhere on the terrestrial mass fractionation line, but it is temperature that determines exactly where. Thirty years of careful laboratory work has gone into a technique known as "oxygen isotope geothermometry." This method is now used to determine the ocean temperatures at which a broad selection of events took place in the past.

What has excited the cosmochemists is the relatively recently discovered exception to the rule: the isotope ratios in the Allende meteorite.

The Allende meteorite is one member of a class of meteorites thought to represent the most primitive, original materials which solidified in the very early stages of the formation of the solar system, a class called "carbonaceous chondrites." Following the discovery of anomalous isotopic ratios in the Allende meteorite, the cosmochemists rushed to analyze the isotope abundances of the other carbonaceous chondrites in their collections, and found that they, too, all had anomalous oxygen isotope abundance ratios.

A region rich in gas, dust, and newly forming stars, IC 1318 in Cygnus. Lick Observatory photograph.

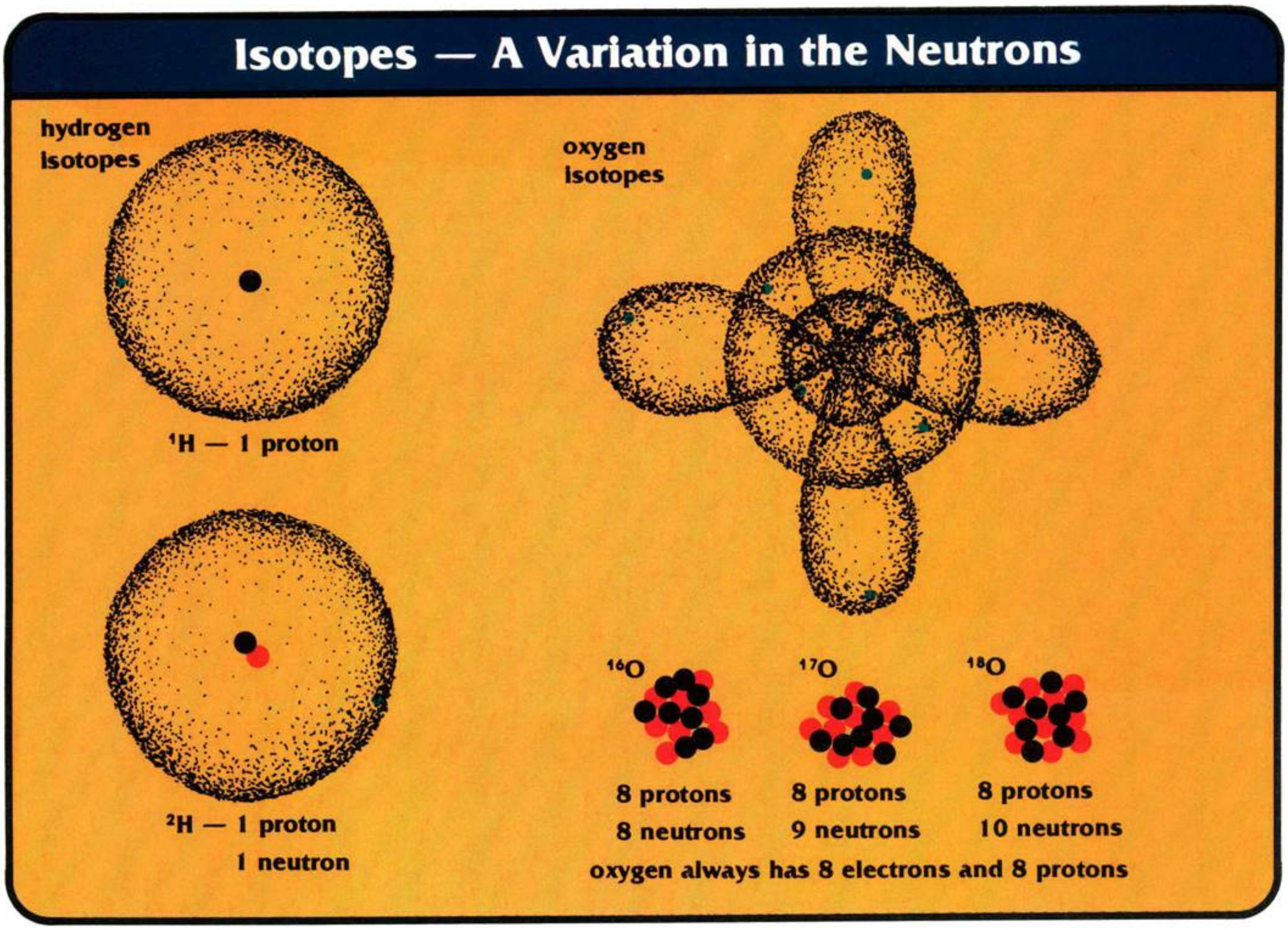


The isotope ratios of carbonaceous chondrites can *not* be derived from terrestrial abundances from any chemical or physical separation process occurring naturally, but they *can* be obtained by mixing terrestrial-type material with a sample of nearly pure ^{16}O. By mixing in a dose of pure ^{16}O, the ratios of ^{17}O to ^{16}O and ^{18}O to ^{16}O change by one unit each.

The mystery then becomes the source of the nearly pure ^{16}O. The simplest way to obtain a nearly pure sample of a single isotope in nature is through nuclear reactions — fission or fusion reactions. Nuclear fission is the breaking up of heavy nuclei (such as ^{235}U) into lighter nuclei; it is this process geologists and astronomers use in dating rock samples and meteorites. Nuclear fusion is the joining of light nuclei to form heavier ones; it is this process that provides the source of energy for nearly all stars. In fact, it seems that all the elements heavier than hydrogen and helium found on Earth were formed in the cores of stars — from hydrogen and helium — by nuclear fusion reactions.

In stars like our Sun, the most important nuclear reaction is one that combines hydrogen atoms to form helium, releasing considerable amounts of energy in the process. However, the center of our Sun is not hot and dense enough at present to provide the conditions for formation of elements heavier than helium. In fact, our Sun will never develop the conditions necessary for forming the heavier elements. Its internal pressure, according to theoretical models, will remain sufficient to counteract gravity, and will thus prevent collapse as the Sun gradually cools to its end as a stable white dwarf. However, many stars in our galaxy do have centers with high enough density and temperature: in particular, those with masses in excess of five times the mass of the Sun can convert helium to carbon or silicon.

Energy is produced by fusion reactions which combine light elements to make heavier ones. But there's a catch: When elements heavier than iron begin to form, energy must be added to produce them by fusion. As a star ages, it burns hydrogen to helium in its core. Near the surface, conditions never become extreme enough to produce fusion reactions, and since there is little or no mixing from inner to outer layers, the outside of the star remains "unprocessed." A star can thus continue to derive energy from fusion until it's built of many concentric layers — an iron core surrounded by shells of silicon, oxygen, neon, carbon, helium, and hydrogen. A shell of nuclear fusion reactions between the H and He shells may convert H to He; between the He and C shells there may be fusion reactions converting He to C; and so on to the center. In each of these shells a number of isotopes may be produced by slightly different nuclear reactions. The "normal" terrestrial mixture of ^{16}O, ^{17}O, and ^{18}O almost certainly emerged from such an environment.



Isotopes — A Variation in the Neutrons

Eventually, conditions in the center of the star may become hot and dense enough to fuse iron atoms into even heavier species — gold, platinum, uranium and other rare and valuable elements. This causes problems for the star, however, because now, instead of releasing energy, the nuclear reactions at the star's center absorb energy. As soon as this occurs, the star's core cools, and the star collapses. In massive stars, collapse invariably leads to a violent explosion known as a supernova.

Most of the star's material is thrown out into space — material rich in everything from helium to uranium and beyond is ejected and only a pitiful tiny remnant of the star is left behind.

The material thrown off in a supernova explosion contains some interesting isotopes and isotope ratios. Most relevant: It contains oxygen that is unlike the terrestrial mix — in fact, it's almost pure ^{16}O. Any ^{17}O and ^{18}O produced during earlier shell burning stages are destroyed in the intense nuclear reactions in the supernova explosion. Here, at last, is a possible source (and, at the moment, the only plausible source) of the excess ^{16}O in the carbonaceous chondrites. All we need is a relatively nearby supernova to contaminate our meteorites as they form!

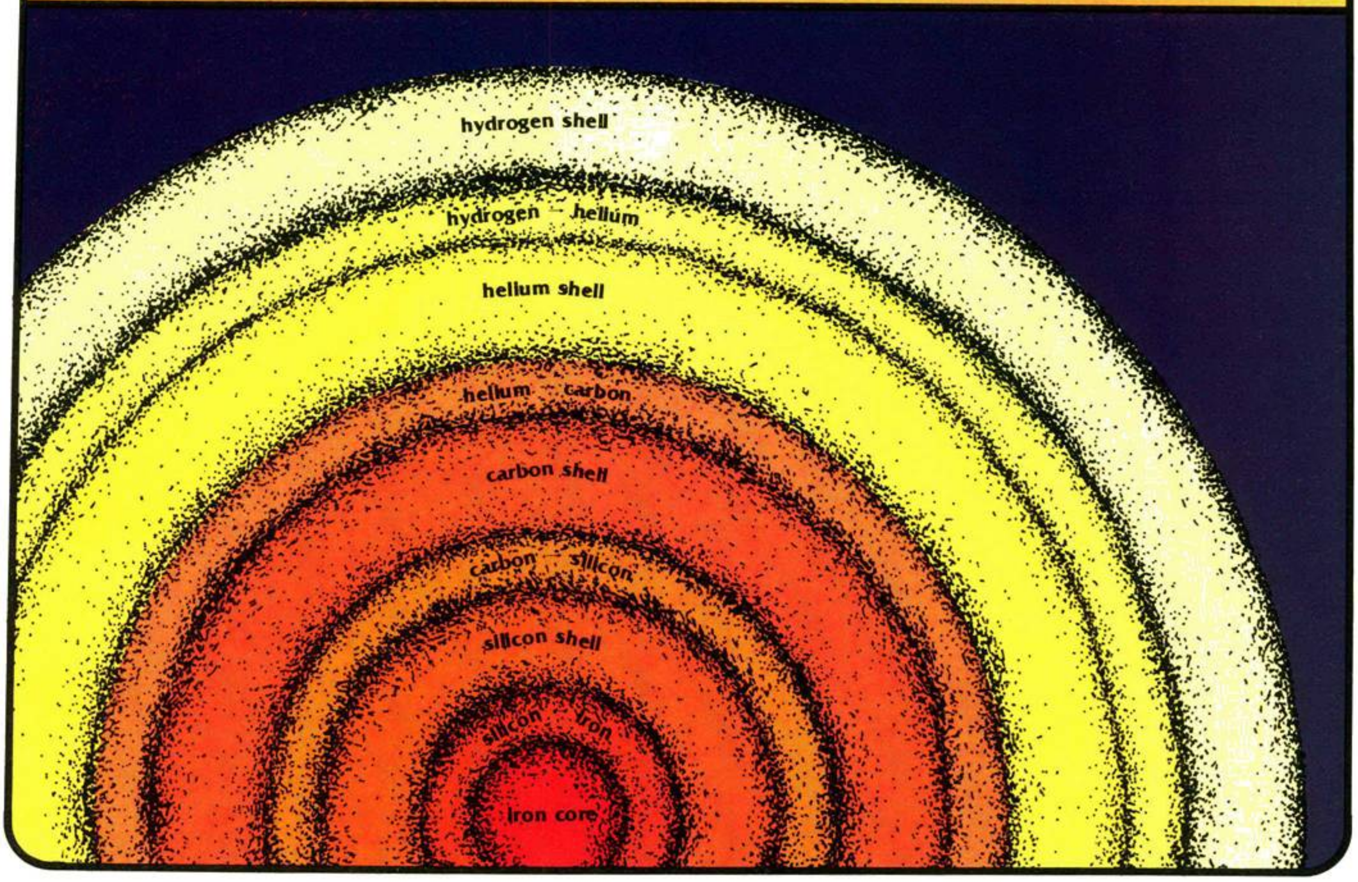
Dramatic support for the supernova theory comes from an even more startling analysis of the Allende meteorite. Typhoon Lee, a cosmochemist working at the California Institute of Technology on the magnesium isotopes in the Allende samples, found a very strange pattern indeed. Magnesium has three stable isotopes, ^{24}Mg, ^{25}Mg, and ^{26}Mg. Lee found that the meteorite was enriched in ^{26}Mg relative to terrestrial rocks, and that this enrichment could not be explained by a naturally occurring sorting process. He noticed, however, that the ^{26}Mg was enhanced whenever the sample had aluminum in it — the more aluminum, the more ^{26}Mg.

Now, one way to obtain pure ^{26}Mg is to let the unstable isotope ^{26}Al decay. After a mere 750,000 years, half of the sample will be ^{26}Mg; the other half will still be ^{26}Al. After 1,500,000 years, ¾ of the sample will be ^{26}Mg, and so on. Lee concluded that the reason the extra ^{26}Mg correlated so well with aluminum concentrations was that the ^{26}Mg originally was aluminum — ^{26}Al, in fact. After the meteorite formed, with chemical and physical processes concentrating the aluminum isotopes in some parts of it, the ^{26}Al decayed to form the ^{26}Mg that remains.

The time scale here is critical. In only a few million years any sample of ^{26}Al will be entirely converted to ^{26}Mg. This is a very short time span astronomically — comparable to the time it took the solar system to form. It is only a thousandth of the present age of the solar system. The unstable ^{26}Al must

Photograph on overleaf: The core of the Orion Nebula is a region of vigorous star formation. The seven brightest stars in the picture are extremely young and massive, rapidly burning hydrogen and helium into heavier elements in their cores. Stars of this type explode within a few million years of their formation, spreading heavy elements into the gas clouds that gave them birth, triggering further episodes of star formation. Lick Observatory photograph.

A Pre-supernova Star



have been incorporated into the meteorites less than a few million years after the supernova exploded.

The anomalous isotope abundances in the carbonaceous chondrites can thus all be explained easily by the hypothesis that the meteorites formed soon after a nearby supernova exploded. But is it also necessary that the solar system formed at the same time and place? It seems to be, because the ages of the carbonaceous chondrites are all the same, and that is the same age as our Sun (4.5 billion years, give or take a few tens of millions of years). The stars near the Sun are of much more widely varied ages, from nearly 10 billion to less than 1 billion. If the meteorites were not originally part of the solar system, then their ages should vary by much larger amounts than they do. After all, if the carbonaceous chondrites were not formed together, along with the rest of the solar system, we would have to assume either that all meteorites everywhere were formed by some other unique event or that by remarkable accident we have inherited meteorites from only one event.

Thus the meteorites tell us about the origin of our solar system, *and what they* tell us is that our solar system formed near a supernova.

But isn't this a far-fetched idea? It certainly seemed unlikely when it was first suggested. Star formation is so common and supernova explosions are rare. There are over 100 billion stars in our roughly 10-billion-year-old Galaxy — so that on the average, 10 stars have formed each year since the Galaxy was formed. But the number of supernova explosions in our Galaxy is between one and 10 per century.

We're forced to go back and ask once again: Is the Earth, or the Sun, unique and special, or are we living in a typical system of planets around a perfectly ordinary star? If we had posed that question to the experts of the centuries preceding Copernicus and Galileo, we would have been told that of course the Earth is unique and distinct from the heavens, and the Sun is the only such object anywhere.

From Copernicus and Galileo through Newton, Einstein, and Hoyle modern astrophysicists have depended increasingly on the assumption that the solar system is *not* unique, that anything we learn from studying our system probably applies to most of the other stars and stellar systems in the sky. This assumption is derived from the basic assumption underlying all of astrophysics: that lessons learned in the laboratory apply even in the most distant astrophysical systems. Indeed, without this assumption we could make no progress in understanding the real nature of stars.

The subtle evidence of isotopic anomalies that led cosmochemists to suggest that the solar system might have formed in the neighborhood of a supernova explosion met, initially, with considerable resistance in the astronomical community. Philosophically, it seemed like a giant step backward, a viewpoint opposite from the trends of the last 500 years. Gradually, however, supporting evidence has been gathered from other areas of theoretical and observational astronomy.

Observations of a number of nearby supernova remnants — material ejected from relatively recent supernovae — revealed intriguing little knots of dust and gas, possibly stars in the process of formation. This suggested to the observers that while most stars may form without interference, it is possible to "trigger" star formation in the interstellar medium by exploding a supernova. This means that we don't need to invoke an unlikely coincidence to explain the oxygen anomalies. Instead of: "A supernova just happened to go off nearby while the solar system was forming," astronomers can say "Our solar system happens to be one of those systems whose formation was triggered by a supernova explosion."

Knowing that some stars are formed as a consequence of a supernova explosion made the hypothesis that our Sun is one such star far more acceptable; the meteoritic isotope evidence suggests that our Sun is one of those "relatively rare" stars. Or is it so rare — how common or uncommon *is* the triggering of star formation by a supernova?

Supernova remnants much younger than 100,000 years old — especially those one to ten thousand years old — are easy to detect, but they're much too young for us to be able to tell whether they will trigger star formation. Supernova remnants older than 100,000 years are difficult to detect. On the other hand, it takes a star like the Sun roughly 1 to 10 million years to collapse from interstellar densities to the point where we can recognize it as a young star.

But recent advances in observational techniques have proven valuable here: radio and infrared astronomers are now able to detect stars in the process of formation much earlier than can be done using conventional optical techniques. Why? Radio waves and infrared radiation can penetrate the cocoonlike clouds of dust and gas that surround protostars. At the same time, advances in radio astronomy have made it possible to study much older supernova remnants. By probing regions which were the sites of supernova explosions a few million years ago, these astronomers have succeeded in finding very young — and presumably supernova-triggered — stars.

The question is no longer "Do supernovae trigger star formation?" but rather "What fraction of stars are triggered by a supernova?" Astronomers do not yet know the answer to that question, but it's possible that star formation induced by supernovae may in fact be rather common.

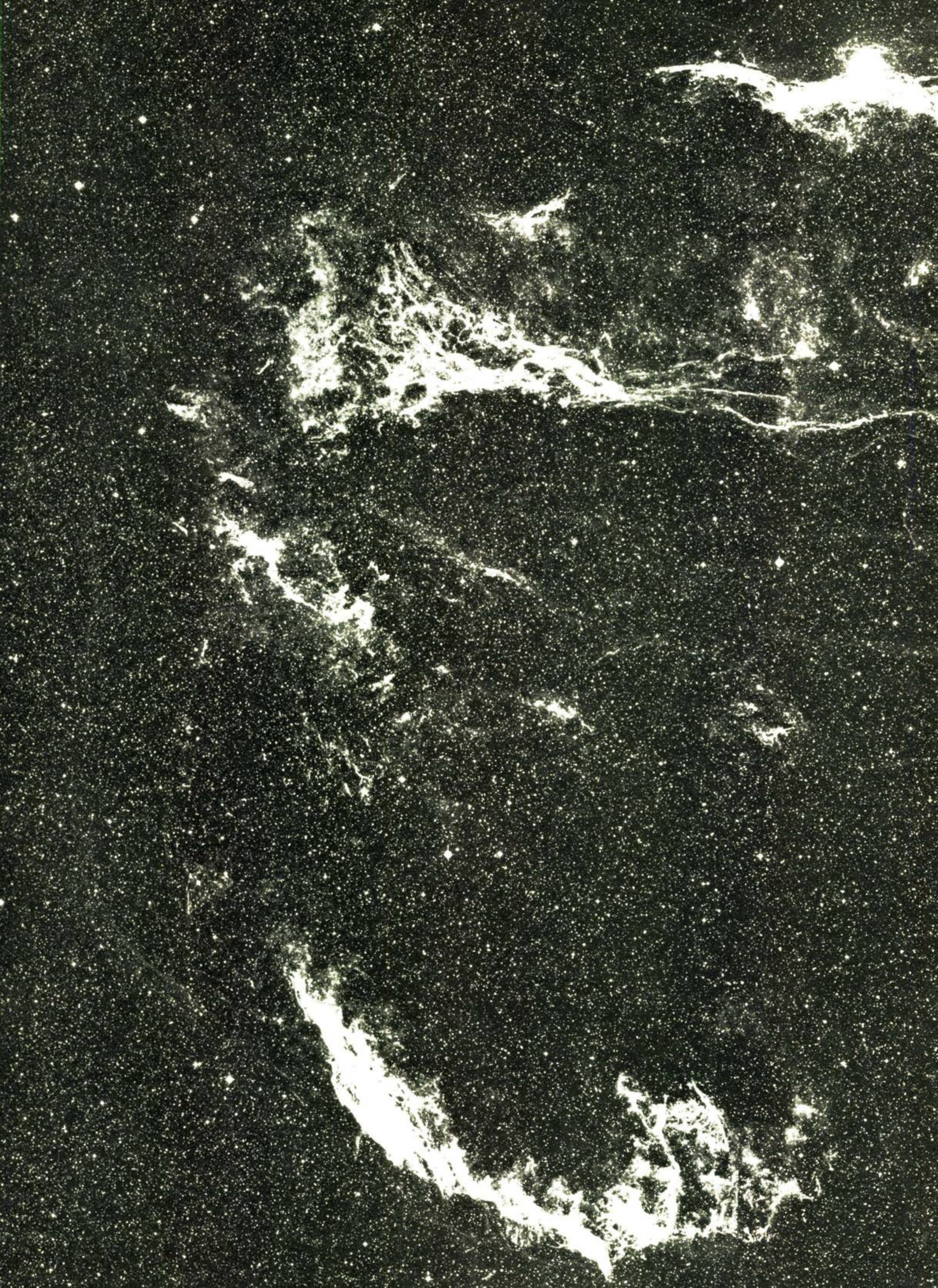
The classical theory of star formation, formulated by Sir James Jeans in 1902, starts by assuming the existence of an interstellar cloud with a specified mass, temperature, and size. A star will form every place where gravity, pulling the cloud together, is stronger than the pressure of the gas which prevents the cloud from collapsing. For a given temperature and density, the theory defines a critical size — the "Jeans length." Clouds that are smaller than the Jeans length will expand; clouds that are bigger will collapse; and clouds exactly that size are indefinitely stable. As a sufficiently large cloud collapses, its mass remains unchanged and its volume decreases; hence it grows denser. Once a sufficiently dense, cold, or massive cloud starts to collapse, it will continue to collapse until some internal heat source such as nuclear fusion raises the temperature and pressure enough to halt the collapse.

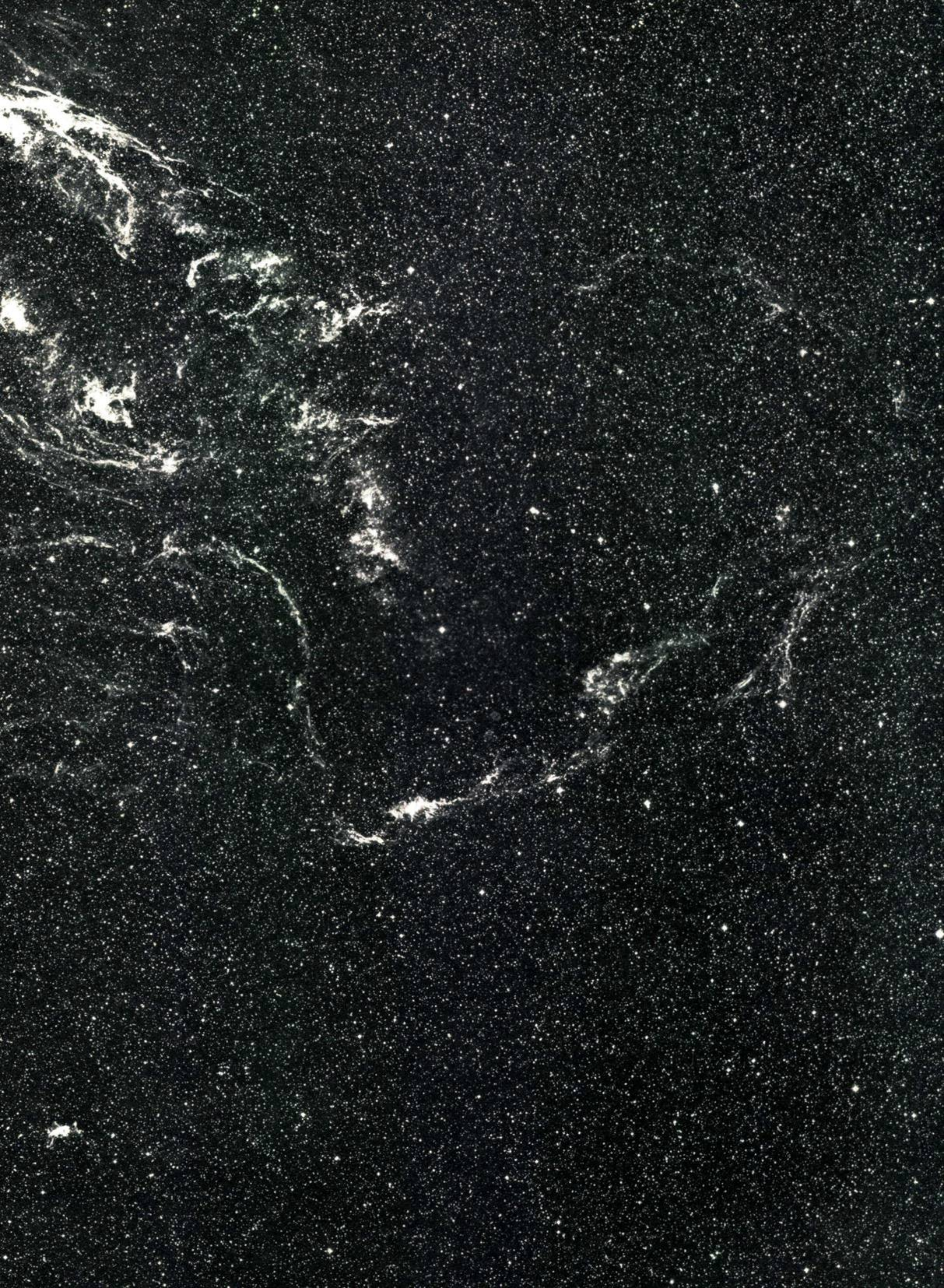
Unfortunately, this very simple and elegant theory predicts that at the typical temperatures and densities of interstellar clouds, a mass of at least several hundred times the mass of the Sun is needed to start the collapse. How then do the small stars —

The little knots embedded in gas and dust are stars in the process of formation. Lick Observatory photograph.

The central star of the Cocoon Nebula illuminates the gases from which it formed. Thomas Dessert photograph.

Photograph on overleaf: A thin shell of glowing gases 70 light-years in diameter and still growing, this supernova remnant called the Cygnus Loop (the Veil Nebula is part of it) will eventually fade and grow dim. This relatively old shell, now some 25,000 years old, is expanding slowly into a dusty and gassy region of space. The central star that caused the explosion can no longer be seen. Hale Observatories photograph.





Density waves can explain the nicely organized spiral arms of type Sa and Sb galaxies. Hale Observatories photograph.

The ragged and complex structure in the arms of type Sc and Sd galaxies can be simulated with a large computer, as shown in color on this photograph of the spiral M-81. Chains of supernova explosions trigger further star formation, hence more supernovae — and still more new stars. Galactic rotation then "smears" the explosion chains into long irregular streaks of bright young stars. Diagram based on work by Gerola and Selden at IBM.

stars like the Sun — form? Most theories of star formation have assumed that as a very large cloud collapses, it breaks up — or fragments — into smaller and smaller clouds. Instead of forming a single very massive star, each cloud forms a cloud of normal mass protostars which continues to collapse, according to the Jeans' theory, because its density has become very high in the initial collapse of the large cloud.

By our presently preferred theories, then, stars can be formed mainly in moderately large clusters of hundreds to thousands of stars. Such large clusters of relatively young stars do exist. Two very familiar examples are the Hyades and the Pleiades, both in the region of the constellation Taurus. (See "Swarms of Stars: Cosmic Calibrators," ASTRONOMY, March 1978.)

On the other hand, associations of young stars have been found to contain several distinct subgroups of differing ages, each containing relatively few stars. Investigating these associations led astronomers to suspect the associations represent examples of supernova-triggered star formation. Their scenario: After a first generation of stars forms in such a region, the massive stars evolve quickly and finally explode in a supernova. This supernova triggers another wave of star formation which in turn produces more supernovae, and so on. (In fact, isotopic anomalies in the carbonaceous chondrites associated with the now extinct isotope of plutonium, ^{244}Pu, have led to the suggestion that at least two supernovae, separated by a span of 100,000,000 years, predated the formation of our solar system.) The supernova chain model appears to account well for the details of some young associations.

Which of these theories — the Jeans or the supernova-trigger theory — applies to star formation in our Galaxy? The answer: Probably both.

Consider the stages of the formation of our Galaxy, stages quite well-established from studies of stellar ages. The "first generation" of stars in our Galaxy, which must have formed without any supernova triggering, is found primarily in great globular clusters of thousands of stars — in accordance with the predictions of the Jeans theory. After some of the first generation stars exploded as supernovae, throwing off material enriched in heavy elements from helium to uranium, a second generation of stars began to form. The second generation stars are found in the flat plane of the Galaxy.

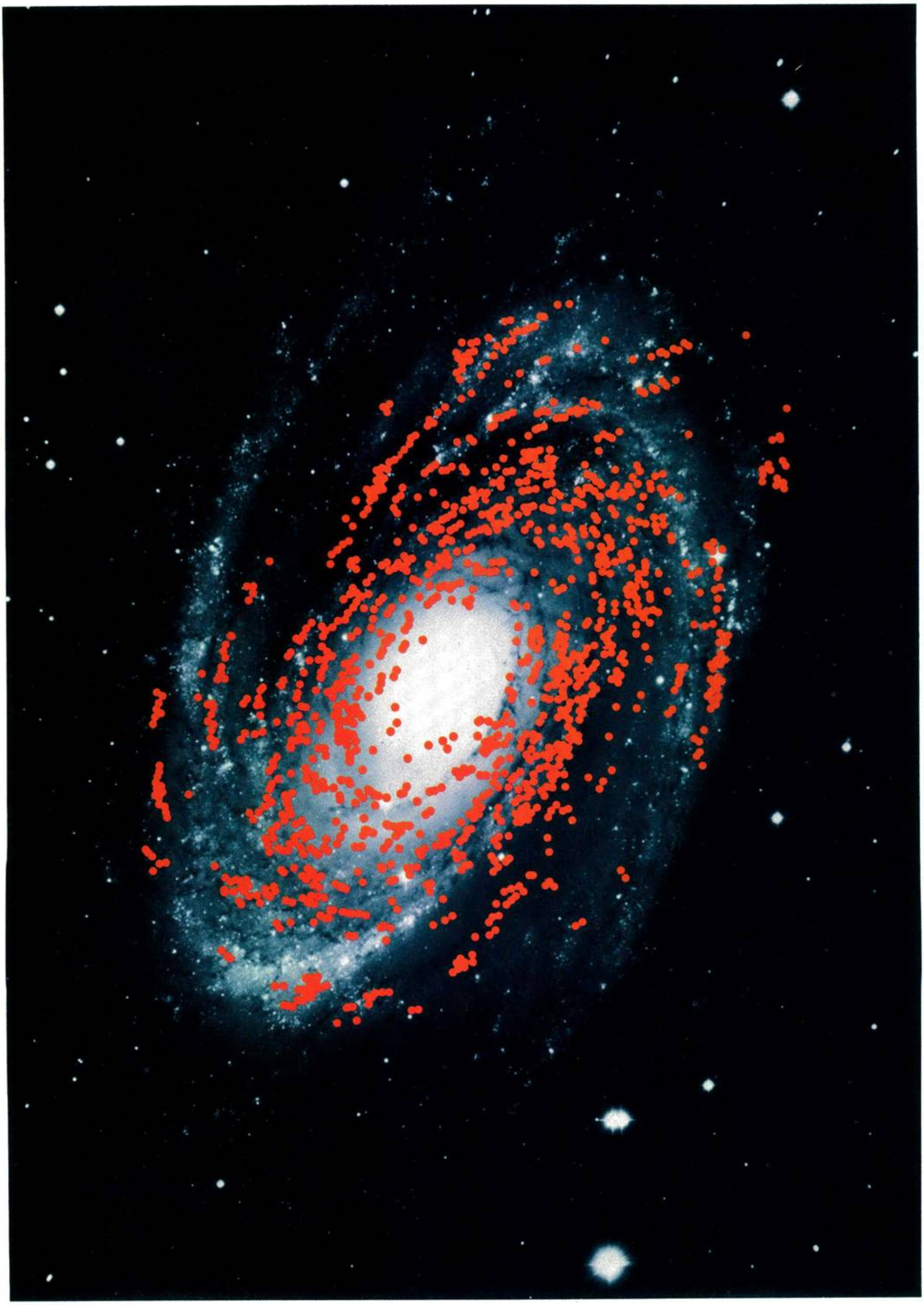
The oldest second generation stars are about 5 billion years old; there are "second generation" stars still forming near us, in the great gaseous nebulae such as the Great Nebula in Orion. Among these second generation stars, supernovae also occur. Each such explosion triggers another small local burst of star formation — a process that will presumably continue until there is insufficient material left to form stars.

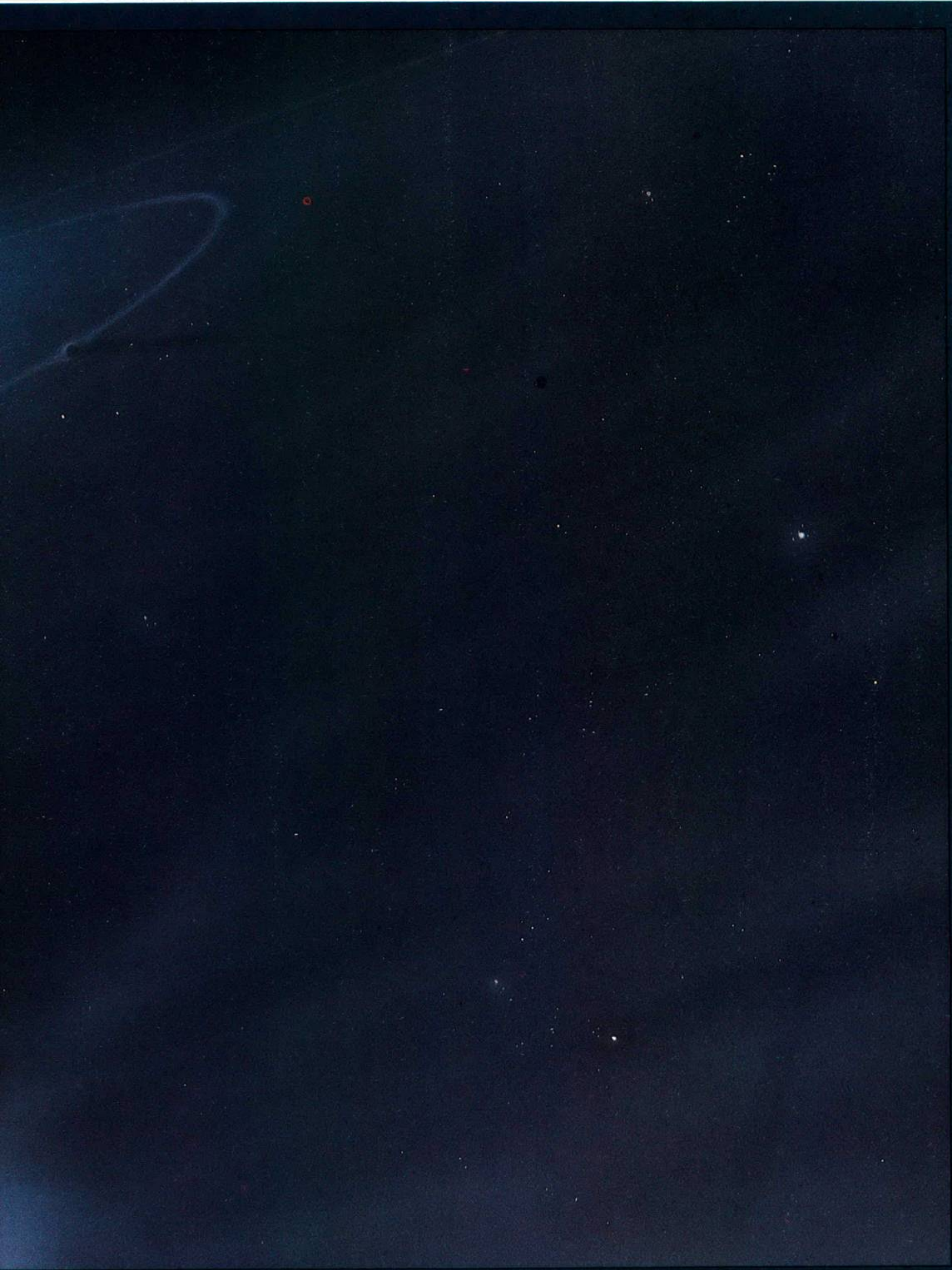
In our own Galaxy, we cannot see most of the supernova explosions that occur because the Milky Way's disk is obscured from view by clouds of dust and gas. Studies of other galaxies and a number of supernova remnants near us, however, show that supernovae occur in our Galaxy at the rate of one every 10 to 100 years. If each supernova triggers 10 to 100 new stars, we can roughly account for the present rate of star formation in our Galaxy.

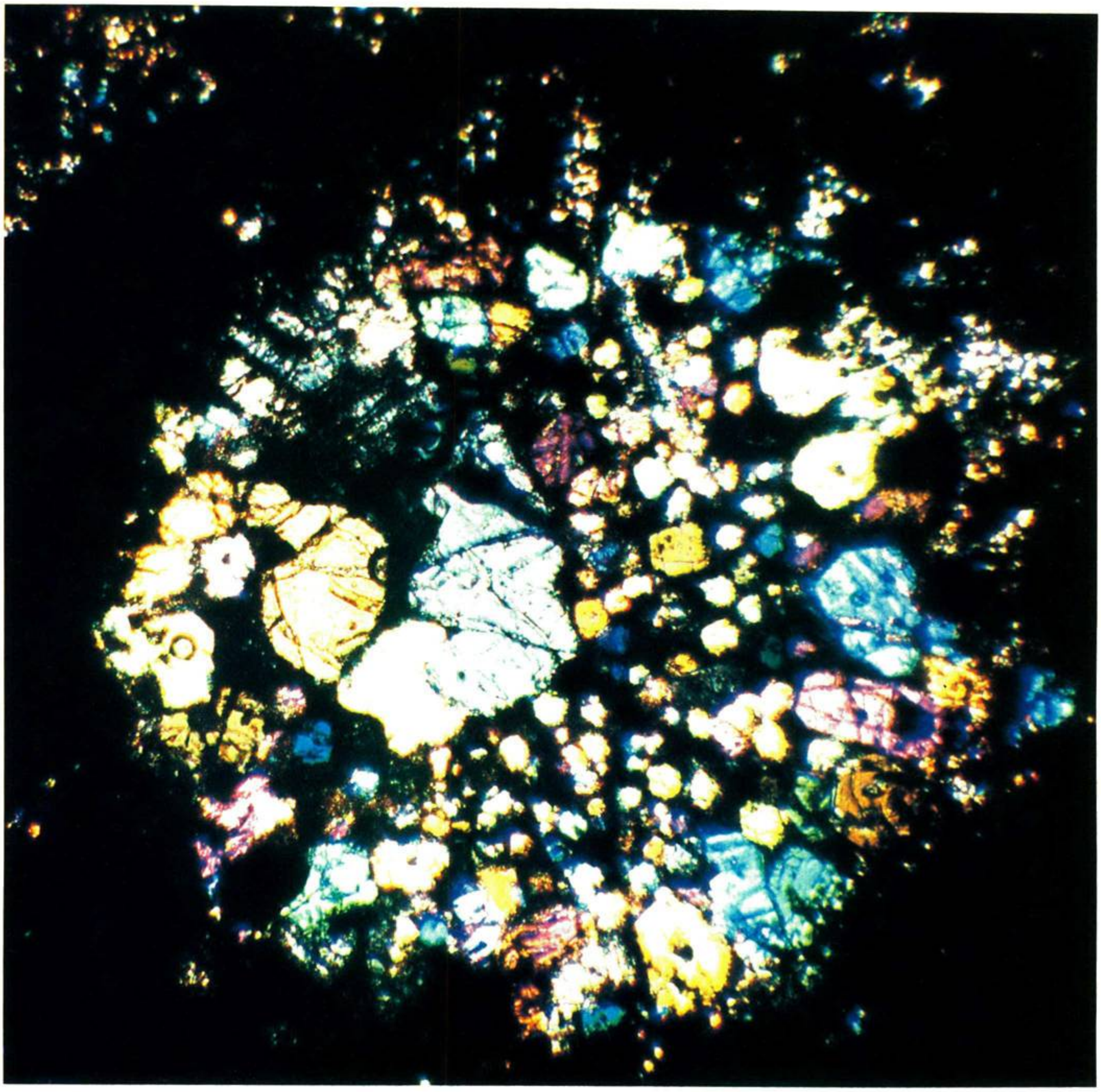
The idea that supernovae trigger star formation leading in turn to further supernovae has been taken one step further by a group of scientists at IBM. Working with some of the world's biggest computers, Humberto Gerola and Philip E. Seiden have calculated the effects of galactic rotation on such "supernova chains." Their results provide a new interpretation for the appearance of the somewhat irregular spiral galaxies of types Sc and Sd.

The usual explanation for spiral arms in galaxies is the "density wave theory" proposed fifteen years ago by Chun C. Lin, Frank H. Shu, and their associates. According to their calculations, a large "density wave" (something like a gigantic sound wave) travels around the galaxy, compressing interstellar material and thus triggering a wave star formation as it passes. Stars are formed in spiral arms but the density wave then moves on; older stars, like the Sun, are expected to lie between spiral arms. The density wave theory does an excellent job of explaining the relatively symmetric Sa and Sb galaxies but does not really explain the Sc and Sd types. As time goes on and more research is done, the supernova chain hypothesis may prove better for the "open" spirals, and the density

Painting on overleaf: Compressed by shock waves and material from a supernova, interstellar gas begins to form a planetary system. The gases flatten into a disk around the new star, and solid materials begin to accrete into proto-planets. Some of the earliest meteorites formed, capturing a bit of material from the supernova, preserve the secrets of their origins for billions of years. Painting by Adolf Schaller.







Chondrules from the Allende meteorite glow under microscopic examination with doubly polarized light. The anomalous ratios of the isotopes of oxygen and magnesium suggested to cosmochemists that materials in this meteorite could not have been made from materials found on the Earth or the Moon. Ultimately it led astronomers to reinterpret a major part of astronomical theory. Photograph courtesy of Steven Richardson.

wave theory for the "tight" ones.

In our own neighborhood in the Galaxy, young stars, dust and gas — the markers of spiral arm structure — are located in two huge and well-defined arms, the Perseus arm and the Sagittarius arm. These two large arms are well-accounted for, both qualitatively and quantitatively, by the density wave theory. The local arm is not; in fact, it looks like a beautiful example of a supernova chain. Both of the theories of galactic structure and both of the theories of star formation may apply simultaneously to our Galaxy.

From the isotope abundance ratios in a little lump of interplanetary rock, to the idea that a supernova triggered the formation of the solar system, through the vast scales of space and time involved in the formation of galaxies, and back again to explain the appearance of the solar neighborhood: these are the hallmarks of a scientific revolution. It began by changing our ideas of a single process, and now turns out to be restructuring our ideas of the Universe. The revolution — and evolution — of ideas regarding the origin of the solar system is truly one of the most exciting developments in astronomy today.

Steven Richardson is a solar system planetologist at Iowa State University and an Assistant Professor in the Department of Earth Sciences. Lee Anne Willson, an Associate Professor of Physics at Iowa State, has written for ASTRONOMY before; see "Why Do Planets Have Rings?" in the December 1977 issue and "The Dark Sky Paradox and the Origin of the Universe" in September 1978.

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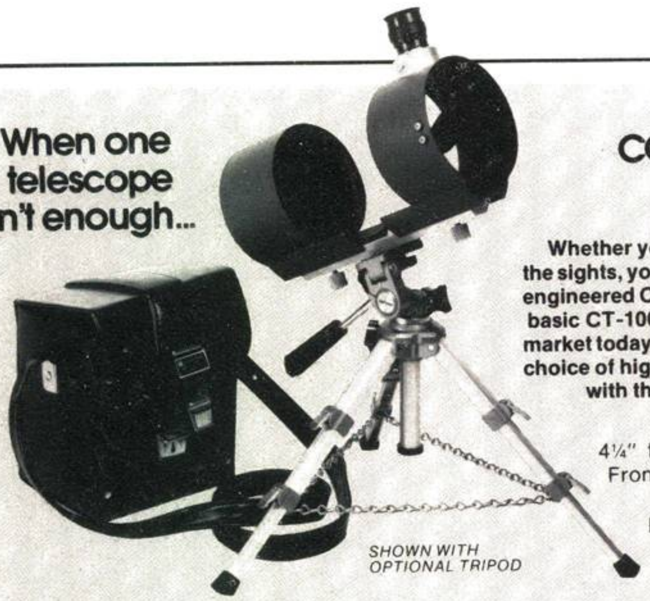

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Pluto's Birthday Party

February 18 this year was the fiftieth anniversary of Pluto's discovery by a young Lowell Observatory research assistant Clyde Tombaugh. It was an event worthy of celebration — and so it was. Herbert Beebe, head of New Mexico State University's Astronomy Department, invited a hundred scientists and journalists for a scientific meeting and celebratory banquet, in Las Cruces, to honor Clyde Tombaugh and discuss what is known about "his" little planet.

It was a treat for me to get away from Milwaukee in midwinter for what I hoped would be a few days of New Mexico sun. The meeting, scheduled for Monday — the anniversary day — promised to be fascinating (after all, what *is* known about Pluto?). 400 of Clyde's friends and relatives were expected at the banquet that evening. And the day before was to include a trip to Sacramento Peak Observatory, a solar observatory located high in the Sacramento Mountains of eastern New Mexico.

Sunday dawned in drizzling rain. As I walked toward the Holiday Inn, I could see Herbert Beebe talking to a small group: "...I've talked to the police and the observers at Sac Peak. It's foggy and snowing hard. The entire road is closed." So the trip to Sac Peak was off.

But the weather was good at White Sands National Monument — so into NMSU cars and off across the desert we went. I ended up in the car with Jim Cuffey, a long-time NMSU professor now at Indiana University, Adrian Herzog, an infrared astronomer, and graduate student-cum-driver Julien Christon and his wife Deb, who was along for the ride. We drove east from El Paso, through the pass in the Organ Mountains, and into White Sands Missile Range.

This is atom bomb country. The Trinity blast was only 60 miles north of here. Herzog seems to know missiles inside out. He's eaten lunch at the Trinity site. Souvenir hunters have already grabbed almost all the trinitite — the nuclear blast fusion crust. Only a bit of the tower remains. They discussed atom bombs which, it seems, need periodic refurbishing. "The problem is the machined surfaces oxidize and have to be repolished." Cuffey thinks the space program is over as a major enterprise — caught between cut budgets and the softening dollar.

As we crossed the missile range, the open landscape was dotted with little white buildings. "They close the road when there's a test on." "The optical tracking stations — those little white buildings — Clyde set them up." "That's where the Army fired the captured German V-2s." "Von Braun used to eat lunch there...." "From the air, the old Santa Fe trail is greener than the desert. From the horse droppings!" This raw new landscape reeks of history.

At White Sands, the road was flooded a few miles in. We stopped and looked at the white sand, the *broad overcast, the* little desert bushes. I talked to Jim Christy, the astronomer who discovered Pluto's

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satellite. He grew up on Milwaukee's South Side. On the way back, we stopped at the missile park at the base. By far the most impressive is the V-2 — a beautifully crude machine. It made a "clonk" sound hollowly when I kicked it. The Redstone rocket (which carried Ham the chimp and later astronaut Alan Shepard into space) is clearly just an updated German V-2.

Back at the Holiday Inn, we still had hours to kill before the evening reception, so we had a few beers. Jim Cuffey is a storehouse of local stories. He told of building the observatory and the road up to it: "Clyde walked ahead and picked out the way and I played Pete the mule with a great bundle of red-painted sticks on my back."

The meeting began Monday morning with coffee and doughnuts. Clyde Tombaugh was there, in heavy demand for autographs, signing with apparent bemusement. Then Donald Roush, acting president of the university, began the meeting, welcoming the 100 or so scientists filling the room, and Reta Beebe promised them: "When we find a planet that's real cloudy, we're going to name the surface features after politicians." Laughter, the formal introduction of Dr. Clyde Tombaugh, discoverer of Pluto, Special Honoree at this meeting, then down to the business at hand: the nature of Pluto.

Ed Bowell, of Lowell Observatory, led off, discussing the size and brightness of Pluto, followed by Ed Tedesco, University of Arizona, on the photometric behavior of the planet. Larry Trafton explored the open question of Pluto's atmosphere (On the "Yes" side of the issue), and Ed Barker refuted (with the "No" side). Mark Lupo, a graduate student from M.I.T., delved into the physics and mechanics of Pluto's interior — what ices, what rocky material — then Dale Cruikshank compared Pluto to the other objects in the outer solar system in search of cosmochemical clues to its origin.

J. Derral Mulholland, of the University of Texas, told how his special electrographic camera had failed to resolve Pluto's satellite Charon; then Harold Reitsema and Faith Vilas of the University of Arizona showed their pictures, taken with a CCD camera, of the satellite. The images obtained by the camera had been separated with the aid of a computer only days before. Naturally, they were very pleased.

The afternoon paper sessions were devoted to Charon, Pluto's satellite. Jim Christy, of the U.S. Naval Observatory, began by giving credit where credit is due: "Very few have been able to discover satellites to planets before the discovery of the planet itself — so I owe a debt to Dr. Tombaugh," then reported on the discovery and continuing observations of Charon. Brian Marsden chastened the scientists and reminded them that all too often stories of new discoveries turned out to be unchecked and inaccurate. He conceded, somewhat reluctantly, that Pluto's moon is real: "The bump will not go away — I suppose. But let's have no more nonsense about satellites of asteroids!"

Clyde Tombaugh told the story of his discovery, and the years that followed it. Very few people know that he continued the search for "Planet X" for another 17 years, spending 7,000 hours blinking plates, covering 70% of the sky, searching for "another Pluto" that was never found among 90,000,000 stars he checked.

Clyde was the star of the banquet held in his honor that evening. There were over 400 people there — friends, relatives, scientists, local amateur astronomers — for a man who had found a planet 50 years before. I sat near the center front by some TV people. "Oh he's a really nice person. I remember when I was in 4th grade and he came to talk to my class. We thought he was so neat," said young Jo Galvan of KRWG-TV.

"We're here tonight to honor Clyde Tombaugh — and we'll try to get to him," said Harold Beebe as he began the program with his Welcome. Then came the Reflections, the Remarks, and finally the Presentation: "Be it known that for his exceptional achievement in the discovery of the planet Pluto, ninth major planet in the solar system; for his lifelong devotion to astronomy through research and teaching; for his instilling zestful and enthusiastic appreciation of science in his colleagues, his students, and the public, the Board of Regents hereby awards the Regents Medal to Clyde William Tombaugh in ceremonies at Las Cruces, New Mexico, February 18, 1980."

— *Richard Berry.*

The End of Myth?

The recent fabulous success of the Voyager close encounter with Jupiter has kept all of us who followed it spellbound with its revelations of beauty and lore transmitted home daily, and has us eagerly anticipating the close encounter with Saturn to come later this year. It has been one of those experiences that makes us grateful for living in this time. But it is distressing that amid all the discoveries comes the empiricist's assumption that a splendid and beautiful peek into the physical workings of the solar system removes the need for myths — supersedes them and makes them irrelevant — especially when this persuasion is indulged by authorities such as the distinguished astronomer Dr. Carl Sagan.

The matter is worrisome to those of us who work with the nature, function, and value of myth. It is as if Voyager were seen as some kind of heaven-wandering bird, reaching down, surgically removing the clutter of ancient foolishness from the thinking of earthbound mankind below. According to this point of view, myth is an ignorant formulation of scientific lore that can now be replaced by better scientific lore the way one scientific theory is displaced by a better and more comprehensive one: as, for example, Newton's laws of motion are qualified by Einstein's theories of relativity.

But that is not how mythology works. Oh, it is true that myth commonly employs cosmological geography as a means of organizing its materials. Thus one can get a pretty good idea of a classical astronomy that may no longer be scientifically relevant from the constellations employed by Ovid. And Dante's *Divine Comedy* employs a medieval cosmology that no one aiming a pea shooter at a planet would want to use. Homer's great poems the *Iliad* and the *Odyssey* did contain sufficient accurate geographical data to be useful to the nineteenth century German archaeologist Schliemann in his successful attempt to locate and dig up Troy. But Homer is not more valuable than Dante for having employed structural data that was scientifically useful, and the inference has to be that the presence or absence of scientific fact is not a significant factor in the value or analysis of myth — for myth is "about" something else.

Myth is about meaning and value — about the significance of everything man does — including poking his fingers into the distant heavens. It illuminates and clarifies, provides the basis for argument and allegory. But it is not subject to

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This photograph of our Moon was taken through a Quantum Four under fair seeing (steadiness) conditions using a photo Barlow lens and H & W VTE film. It shows the Hyginus-Triesnecker area including the craters Manilius (bottom left), Agrippa, and Godon. Part of the magnificant Ariadeus Rill comes in from the left toward Hyginus, and the craterlet chain nature of the Hyginus Cleft can be discerned clearly. The resolution recorded on the original negative is 1 to 1½ arc seconds, but unavoidable losses in printing and reproduction have removed the very finest details plainly visible thereon. Even the best photographic image falls short of revealing what the eye would have seen at that moment.

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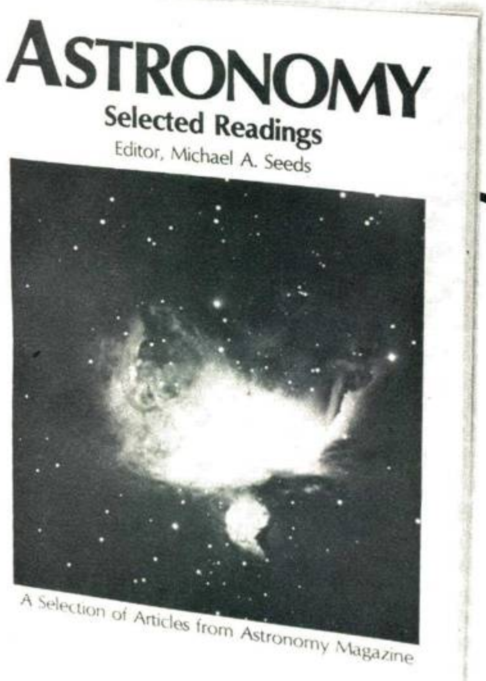

ASTRONOMY
Selected Readings
Editor, Michael A. Seeds

A Selection of Articles from Astronomy Magazine

proof or disproof because it speaks in the language of metaphor, not of empirical data, and this is true even when it employs empirical data in its metaphoric language.

For example, one of the myths retold by Ovid concerns a young adolescent boy whose name is Phaethon who hears a rumor, confirmed by his earthly mother, that his father is the Sun, and who marches into the heavens — into the very palace of the Sun — to demand if the rumor be true. Helios (the Greek name for the Sun) says that it is — in proof of which he promises to grant a wish of his son's. The son wishes to drive the chariot of the Sun across the sky for a single day. Though the father tries prodigiously to dissuade the son, the wish, having been promised, must be granted. Phaethon tries to steer the chariot and, of course, loses control. He travels too far from this, too close to that (which is how, quips Ovid in the kind of remark an empiricist might seize on to throw out the myth, the Sahara desert was formed). Phaethon is hurled from the chariot and destroyed.

In a descriptive sense, the Sun plainly isn't a person on a grand scale — an anthropomorphic god — who spawns human children by earthly women; even Ovid knew that! But there is a sense — both mythic and practical — in which it does make sense to think of ourselves as children of the Sun and the Earth. Phaethon may be seen to represent mankind — in a sense not refutable by science.

Are we not trying to harness the Sun? And are we not trying to control our dependence on the Sun — to push back the advancing Sahara for one thing? Feminists will note that in the tale of the superior credibility and power of the father over that of the mother lies an issue very much still with us. Environmentalists will find a moral in the myth as I've retold it from Ovid: Whether one thinks of the myth as a noble allegory of human aspiration (to control the sources of energy themselves) or a frightful one of human impertinence (as an analogy of our approach to nuclear energy, for example), it warns of dire consequences in fooling with energy. While nothing can be proved from the myth — hence the dissatisfaction from a categorizing point of view in having the damned thing around — it yet provides a focus for what's worth proving.

In doing so, myth illuminates daily life more than is commonly realized. We use the myths to say what we mean even though we may not know them directly.

Whenever we speak of a leader's rise, moment of glory, and fall, we are making a not too distant analogy with a solar myth — the progress in human form of the Sun across the planet. Whenever we refer to people in movies as "stars" we are making another astronomical analogy clarified by myth: they are distant, inaccessible, remote, beautiful, and they do their work for us in or after dark — the time appropriate for stargazing and fantasy. These entertainers are given the form of things beautiful and far away, and one relates to them in one (or both) of the following ways: I could never be like that; if only I could be like that. The power myth has over us can be appreciated by contemplating the social consequences of replacing the starry metaphors embedded on Hollywood Boulevard with squares.

The examples are as various and fertile as the language. Since they have been around for a long time, myths form a public language appropriated by the fine arts and by humanistic discourse throughout the ages.

When Dante begins his wonderful poem telling me that he awoke in the middle of his life to find himself lost in a dark wood, I think I know what he means — even if an empiricist would tell me that there weren't any forests in Italy in Dante's time or that, if there were, Dante never slept out in them. The truth or falsity of such details may well be interesting in its own right, but it tells us nothing about how to read the *Divine Comedy*.

Myth speaks the language of the mind, not that of the empirical world, and it appropriates the very furniture of the heavens in order to do so. If the furniture can be described more accurately, so much the better — and the better descriptions may well alter the language, but not the function, of myth.

Why does it *matter* that we went to Jupiter? Why does it matter that we traveled four hundred million miles to study an uninhabited heap of chemicals when we have lots of those much nearer home? I suggest that the mythic reason for doing so is that the journey extends the dimensions of home; divergent views of what such an extension means for us are expressed in different myths. One myth tells us that we are specks on a small speck wandering around a small speck in a very large place. Like all myths, it is a "true" one. The other myth tells us that we are giants who reach our fingers out into the heavens to touch the distant points of the solar system. And that is a true myth, too.

Man is insignificant and man is majestic: capable of blowing himself out of the cosmos (and the cosmos, so far as we know, wouldn't mind), he is (perhaps) majestic enough not to do so. Whatever the scientist may do with the pictures that come back, the rest of us are using them to sort out questions of human scale: Lords of creation or specks of dust? — the question drives us back to the language of myth in order to cope with it.

Put it another way. The farther away we travel, the more alienated we feel. Far from replacing the need for myth, science creates it, for the farther we go into the unknown, the harder we have to work to feel at home in it. The transformation of empirical observation into a place that feels good to live in is the work of myth. If the work of science is observation, the work of myth is domestication.

I have no doubt that modern mythographers will emerge who can not only withstand modern investigations of space, without repudiating them, but set about the work of making mythic structures out of the investigations. True, initial attempts are not promising: *Star Wars* is too martial, and *Close Encounters of the Third Kind* too sentimental — at least for my taste — but these two films dramatize two ways, equally possible but antithetical, of looking at our enlarged world: as hostile or as fraternal.

In the beginning of this essay I alluded to the Voyager spacecraft as a flying creature threatening to tear the vitals out of myth. Some readers may recognize the myth of Prometheus in the allusion — it is the myth I have kept in mind in order to focus my essay. In the myth, Prometheus brings fire to mankind (which in this context might be read as a mythic convention for illumination, inspiration, art, — that sort of thing). For this deed he was punished by Jupiter (of all people) by being bound to a rock and having his entrails feasted on by eagles each day, only to have them regenerate at night. Classical dramatists and the English poet Shelley thought that ultimately he got out of the bind — an escape that resulted in further gifts of illumination for mankind. When myth itself is no longer enchained by human misunderstanding, it likewise will be free to make gifts of the truths it embodies.

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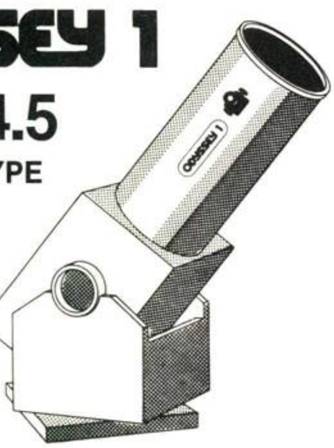

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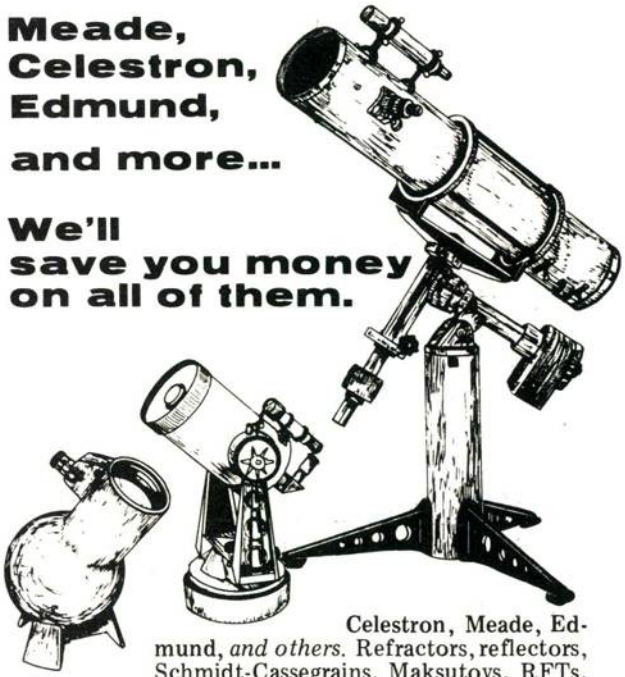

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eye
on the
sky

venus points to mercury

the wanderers

At the end of May and for the first few days of June, the five "classical" (naked-eye visible) planets will all be arrayed in the evening sky. Not a terrifically rare event, this is just a nice chance to get to know them without having to stay up half the night.

This month, luck steps in and offers you an excellent opportunity to locate **Mercury** with little difficulty: About 45 minutes after sundown on the evening of June 1st, go outside and look low in the west-northwest. There you'll see bright **Venus**, shining at magnitude -2.6.

Then take a close look to the right of Venus and you should see the fainter, but still pretty bright, dot of light — that's Mercury, the Sun's innermost planet. At magnitude -0.4, Mercury isn't dim by any means, but most people have a hard time finding it normally because they're always looking for it in twilit skies. So don't pass up this chance conjunction with Venus!

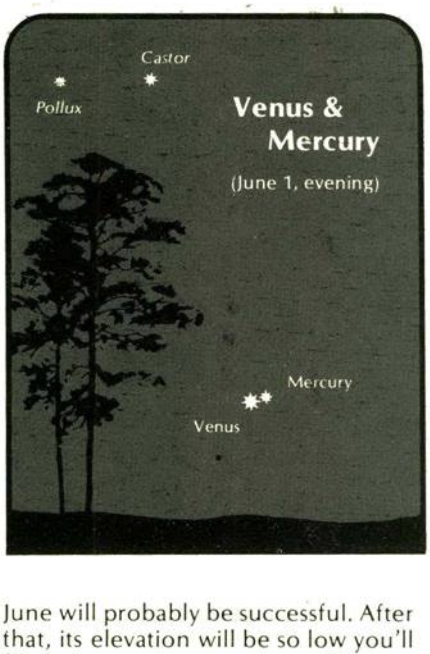
Both planets are in the western part of the constellation Gemini, the Twins. Look about 20° above the two planets where you'll find "the twins" themselves, Castor and Pollux. Castor is the slightly brighter star on the right.

Venus has been finishing its long apparition in the evening skies by rapidly slipping down toward the western horizon on a path that'll take it between the Earth and Sun on June 15th. If you could watch free from the Sun's glare, you'd see it pass just south of the Sun's disk. This point is called *inferior conjunction*.

After sweeping through inferior conjunction, Venus moves into the morning sky where it'll remain until early April 1981. How soon after the 15th can you find it? Weather permitting, it'll be visible during the last week of June, very low in the east-northeast. (Through the Eyepiece this month has a diagram showing its position in the eastern sky over the mornings to come.)

Mercury never strays far from the Sun and is visible only when it is near its maximum angular separation from the Sun. These separations are called *greatest elongations* and there are two types: eastern (seen in the evening sky as now) and western (in the morning sky).

Mercury will reach greatest eastern elongation on the 14th, but its highest elevation over the horizon comes 5 or 6 days earlier. As a result, a search for it any time during the first three weeks of June will probably be successful. After that, its elevation will be so low you'll likely be wasting your time. (The next elongation of Mercury comes at the end of July in the morning sky.)



To find the other naked-eye planets (Jupiter, Mars, and Saturn), look high in the southeast for the constellation Leo; all three are spread west to east through Leo along the ecliptic, "the path of the planets."

Jupiter, the westernmost, is also the brightest of the three. Its clear white radiance is unmistakable. (You won't confuse it with Mars if you remember that the latter is both redder and dimmer.)

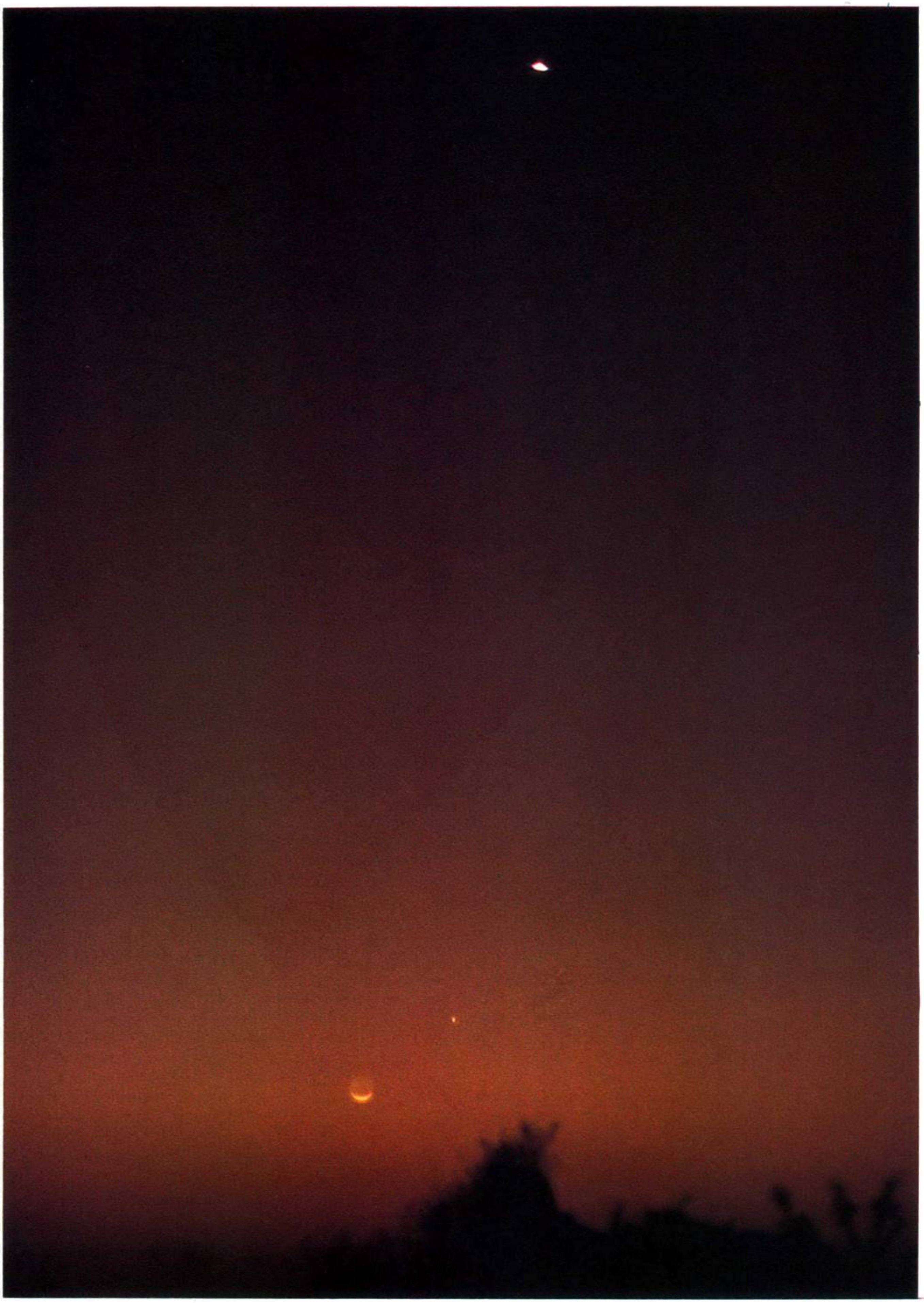
Having spent from last December until this May moving westward to approach (but not quite reach) Regulus, Leo's brightest (true) star, Jupiter has begun to move back toward the east. Night by night, you'll see it creep slowly away from Regulus, until Jupiter and Leo both become lost in the Sun's twilight glow this August.

Flighty **Mars**, ruddy-colored and of magnitude +0.9, won't linger in Leo long enough to be caught by the Sun. Moving steadily eastward from its position between Jupiter and Saturn on the first of the month, Mars overtakes Saturn on June 25th, sweeping by only a little south of it. After its fleeting conjunction with Saturn, Mars continues on into Virgo, passing Spica in mid-August.

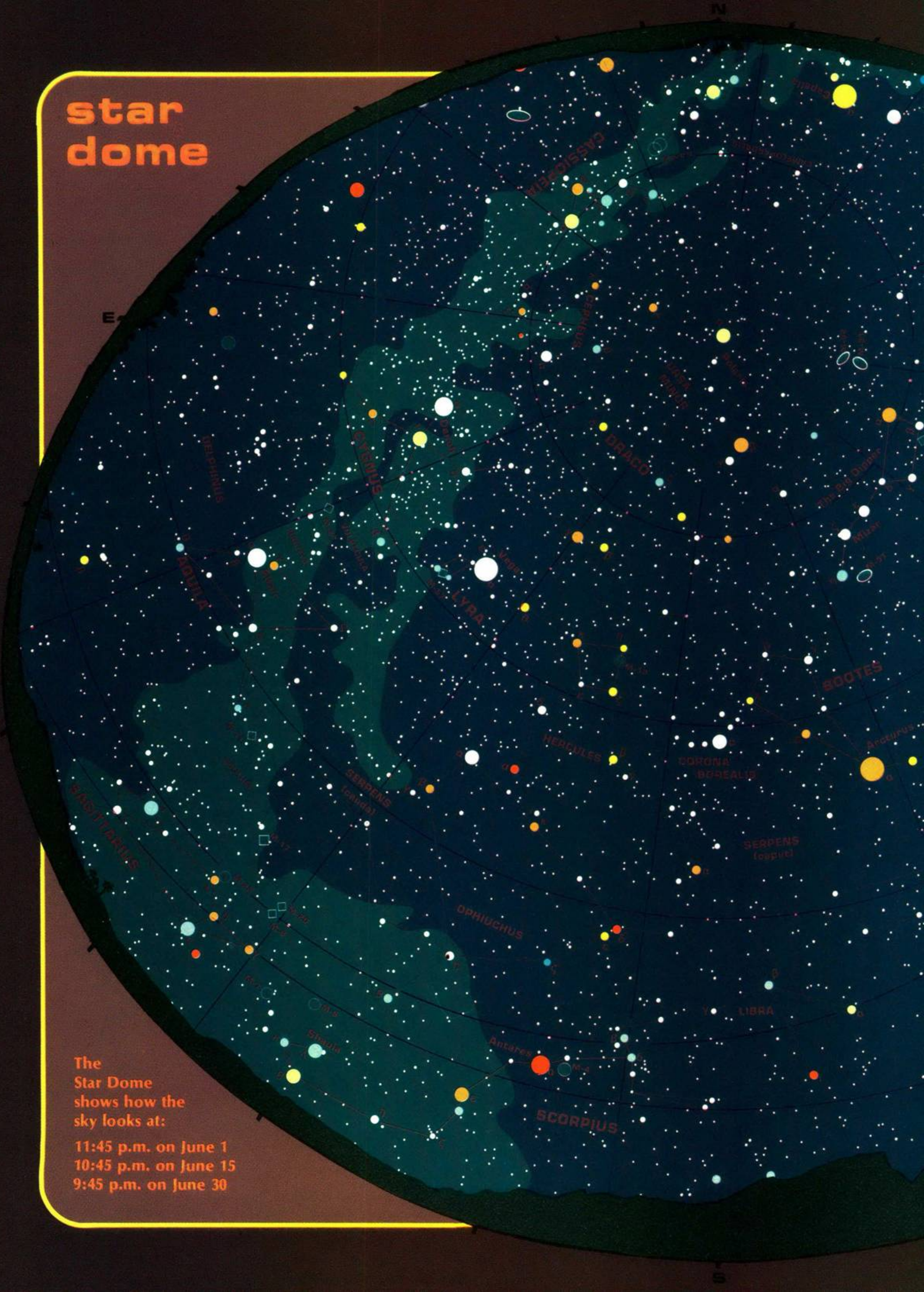
Saturn is the farthest and, at magnitude +1.2, the dimmest of the naked-eye planets. Look for it to the south of Denebola, the star at the tail of Leo. Saturn shines with a slightly yellowish color and would be hard to tell from a real star if you didn't have your Star Dome map of Leo at hand.

With the naked eye, Saturn is something of a disappointment: about all you can see is its slow motion in front of the background stars. But then right now, even if you had a telescope, you couldn't view very much since the famed rings are turned edge-to and couldn't be seen easily.

28 hours after the February 16th eclipse, Chris Huber made this photograph which shows Venus (at the top of the frame) and Mercury and the Moon (at the bottom). He was observing from his eclipse site near Ankola, India, and used a 50 mm lens at f/1.4 with Ektachrome 64 *slide film* and a seven second exposure.

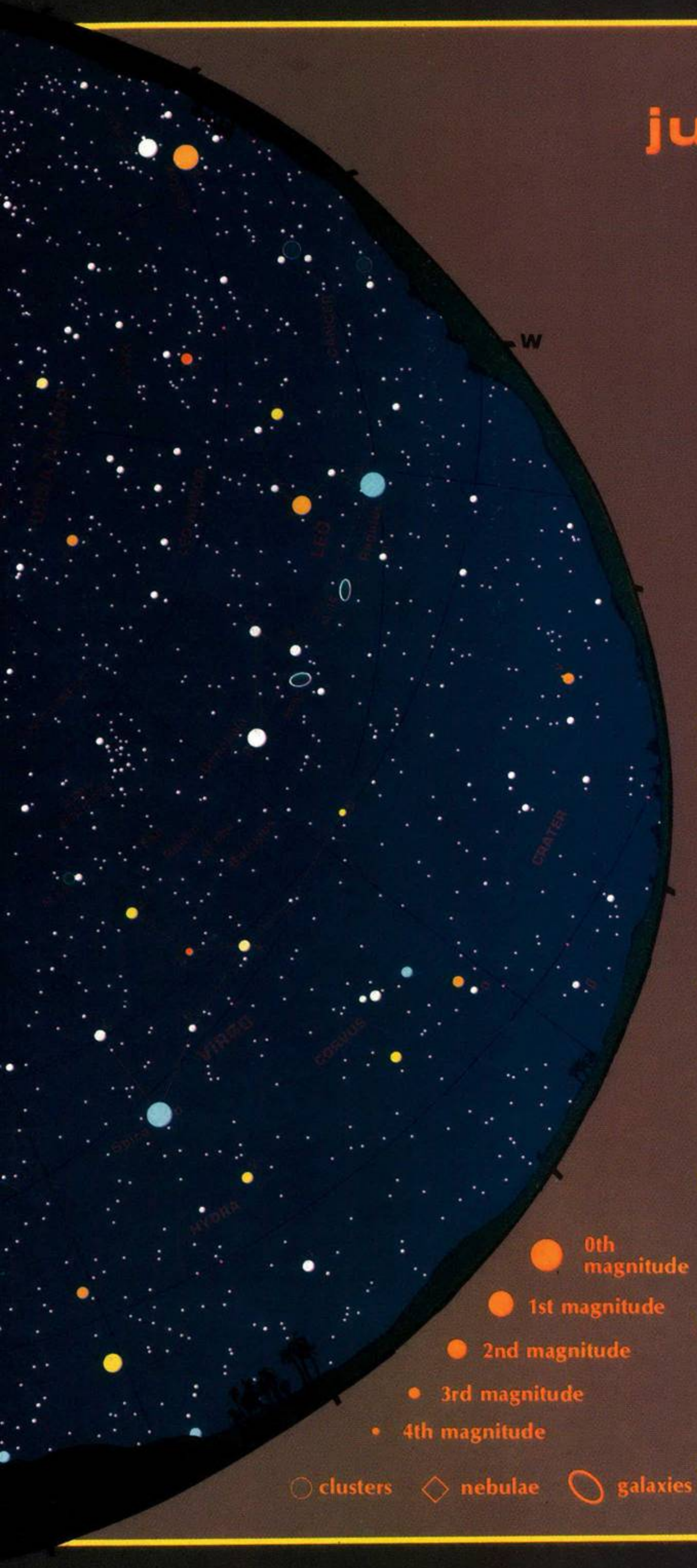


star dome


N
E
S
CASSIOPEIA
Capella
CAMELOPARDALIS
CEPHEUS
URSA MINOR
Polaris
DRACO
The Big Dipper
Mizar
M-81
M-82
M-97
CYGNUS
Deneb
DELPHINUS
Vulpecula
Sagitta
AQUILA
Altair
LYRA
Vega
M-57
M-13
HERCULES
CORONA BOREALIS
BOOTES
Arcturus
SERPENS (cauda)
SERPENS (caput)
Scutum
M-11
M-17
M-20
M-8
M-22
M-7
M-6
SAGITTARIUS
OPHIUCHUS
LIBRA
Antares
M-4
Shaula
SCORPIUS

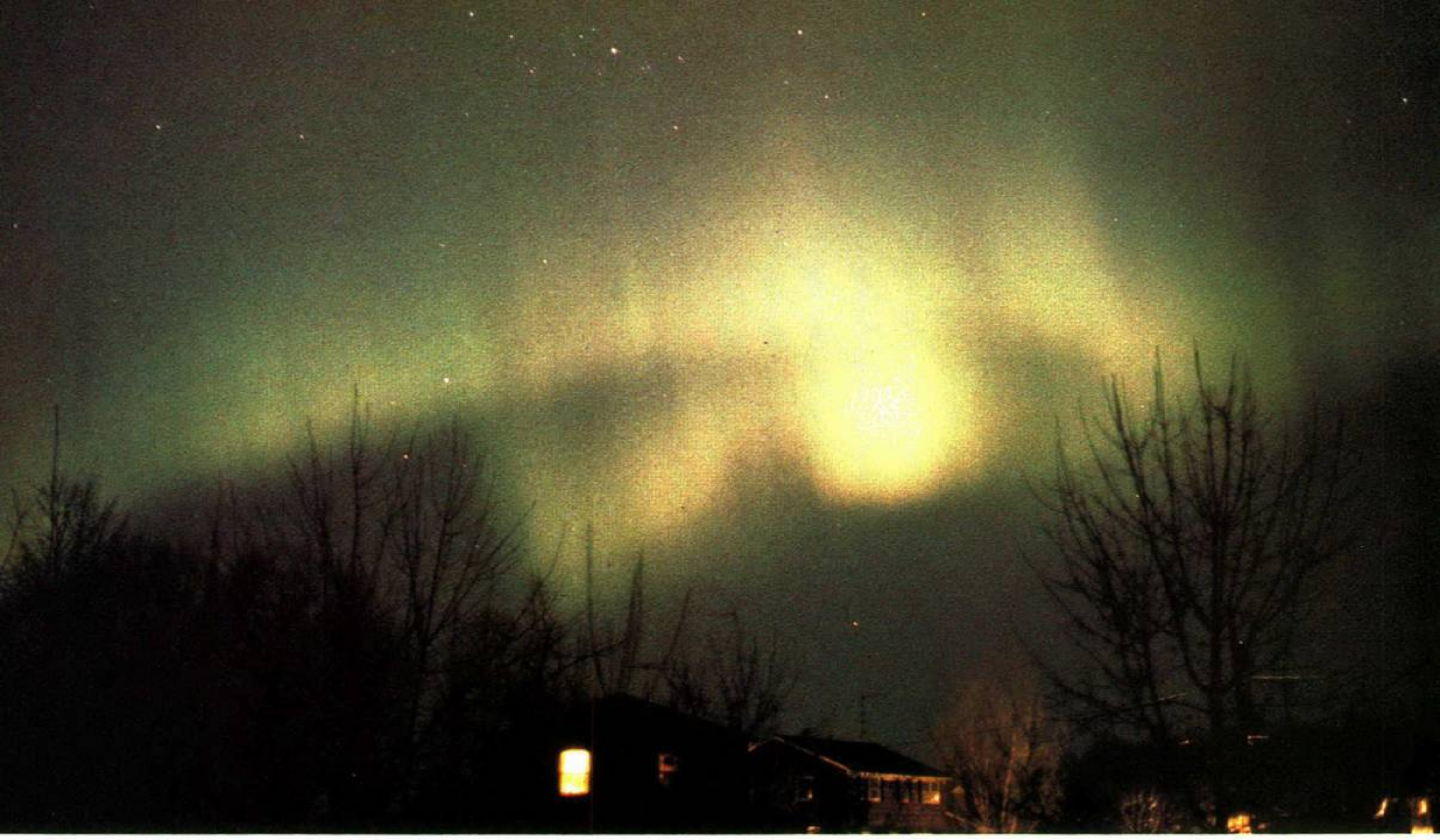
The Star Dome shows how the sky looks at:

11:45 p.m. on June 1
10:45 p.m. on June 15
9:45 p.m. on June 30


W
CANCER
LEO
CRATER
VIRGO
CORVUS
HYDRA
0th magnitude
1st magnitude
2nd magnitude
3rd magnitude
4th magnitude
○ clusters
◇ nebulae
galaxies

sky june almanac

1st	Look for Mercury and Venus very close together in the evening sky tonight.
5th	The Moon is at last quarter tonight. It rises about midnight and won't set until around noon tomorrow. Also: From tonight through the 9th, Mercury will be at maximum elevation in the west-northwest. Start looking just after sunset and look low, about 10° elevation!
8th	The Moon is at perigee (closest to Earth): 227,931 miles.
12th	New moon today.
14th	By tonight Mercury has begun to drop back down toward the horizon in the evening sky. A crescent moon, very slender, will be below Mercury and to the left.
15th	Venus passes between the Earth and Sun into the morning sky.
17th	Tonight, the Moon will be close to Regulus, the brightest star in Leo.
20th	The Moon is at first quarter early this morning. It'll rise around 1 p.m. and set about 1 a.m. tomorrow.
21st	The solstice; summer begins. Also: The Moon is at apogee (farthest distance from Earth): 250,594 miles.
28th	Full moon.



With solar activity reaching its cyclic maximum this year, your chances of spotting an aurora are very good: Whenever you go outside on a clear night, take a look to the north — you might be lucky. A. W. Steinbrecher shot this fine curtained arc using a 50 mm, f/1.8 lens, 400 ASA film and 25 seconds' exposure.

the starry sky

In the more northerly parts of the United States, June is the first time it's warm enough for you to lie contentedly on your back looking up into the dome of the sky after sunset. As the evening sky darkens, the first "star" you'll see is Venus, then Jupiter, perhaps Mars, or farther from the diminishing glow in the west, the singular ruddy glint of Arcturus. Within a few minutes, you'll be able to find the handle of the **Big Dipper** a bit north of dead overhead; then the bowl stars will pop out one-by-one, the lip of the bowl first. Follow the arc to **Arcturus** and swing on down to **Spica** — whitish on the deep blue of the late twilight sky. Spica is the only bright star in the southern skies early on these nights — except for the ruby twinkle of **Antares** climbing slowly out of the horizon's haze in the southeast.

To the northeast, three more luminaries are rising — **Vega**, the brightest and highest; **Deneb**, a bit to the left of and below **Vega**; and **Altair**, *low, due east, at the tip of the Summer* Triangle. On those hot and hazy nights that come in full summer, these three stars will shine — sometimes the only stars visible — straight overhead, and the crisp nights of autumn arrive as the Triangle sinks in the west.

Even if you've never watched the stars come out before, you should have no trouble finding the **Big Dipper**. Nearly straight overhead, its array of second magnitude stars and distinctive outline are hard to miss. The stars have Arabic names: Dubhe, Merak, Phecda, Megrez, Alioth, Mizar, and Alkaid (from the lip of the bowl to the tip of the handle) — an "open sesame" to the constellations. The Dipper is ordered, too, so it doesn't require any sort of mnemonic feat to know the greek-letter designations: Alpha, Beta, Gamma, Delta, Epsilon, Zeta, Eta right down the chain!

Merak to Dubhe (Beta to Alpha) prolonged five times points to Polaris, the North Star. Follow the arc of the handle to Arcturus. Megrez to Phecda points to Regulus; Megrez to Dubhe toward Capella; Megrez through Merak points at Gemini. Phecda through Dubhe prolonged a time and a half locates twin galaxies M-81 and M-82, and M-51 is tucked away between Alkaid and Mizar.

The Big Dipper is an asterism or group of stars that isn't an official constellation. So is the Summer Triangle. The real constellation is **Ursa Major**, or Great Bear. The feet and head of the Bear can be solved any number of ways with the stars west and south of the Dipper asterism. The Bear faces east and his feet point south, tensed under him as if he's ready to spring. What leaves every legend maker laden with tall tales is the Bear's tail, too long for any real bear to trail. Epsilon, Zeta, and Eta make a better handle than a tail.

And the **Little Dipper**? It's really called **Ursa Minor**, the Small Bear, and is much harder to see than the Great Bear. **Polaris** is the tip of the handle in this Dipper, but from cities, only the two stars at the end of the bowl are visible. In darker skies, you can trace the shape of the Little One bent backward toward **Mizar**; the brightest star on the inside of the bowl bears the name **Kochab**.

Once again, follow the arc to Arcturus. **Arcturus** is a K giant star 80 times more luminous than the Sun, 22 times its diameter, 36 light-years away. Its surface temperature is lower than the Sun's, closer to the temperature of an incandescent light bulb than the Sun, and markedly yellower. The constellation **Bootes**, nominally a herdsman, makes a better ice cream cone. Arcturus is the bottom tip of the cone, which is tipped precariously to the east. And on the cone is a scoop of ice cream marked by a cherry on top.

West of Bootes is the little constellation **Coma Berenices**, a loose spangle of faint stars. Coma really is a cluster of stars, just like the Hyades and Pleiades, only about 300 light-years from us. Deeper in space than eyesight alone permits us to reach, a cluster of galaxies spreads across the sky from

Coma down into Leo and Virgo. This region offers hundreds of galaxies all about 12 million light-years away for the perusal of telescope users. Finally, for professional astronomers, Coma has the Coma cluster of galaxies, useful for calibrating the distance to yet-more-distant clusters, at a distance of half-a-billion light-years.

To the east of Bootes is **Corona Borealis**, the Northern Crown. It's fairly easy to see because the stars form such a distinctive arc. **Gemma**, the brightest star, is obviously the jewel in the crown.

After the brilliant stars of the Winter Zodiac, the Summer Zodiac is relatively dull. The long stretch from Leo to Virgo is relieved only by Spica; then there's another long stretch into the brilliant stars of Scorpius and Sagittarius. Between them is Libra.

Libra is a pair of scales, the old-fashioned kind that date back to antiquity, with two pans hanging from a balance beam. Or it's a kite — take your pick.

Libra's stars have beautiful names. The one on the right side (lying almost exactly on the ecliptic circle) is **Zubenelgenubi**. The one at the top of the kite is **Zubeneschamali**. Let these roll off your tongue while you look for this dim constellation — and make sure you treasure all six syllables in each name.

skylore

Nights are short in June, so the time for stargazing is considerably reduced from the long nights of winter. At any one time — say the end of twilight — about 12 hours of right ascension along the celestial equator will be visible. Add to that the length of the night in hours (of which each one will bring another hour of right ascension rising above the eastern horizon), and you will have the total extent of sky along the equator which can be seen that night. During June, with nights at best six hours long, no more than about 18 hours of right ascension are available. But in December, with nights (measured from end of evening twilight to beginning of morning twilight) nearly 12 hours long, practically the whole sky can be seen (provided you are willing to stay up all night).

Of course, the above calculation only works for constellations along the celestial equator. Those farther north spend more than 12 hours above the horizon, and of course eventually we reach the constellations which never set — the circumpolar constellations which are visible somewhere in the sky at all times on every night in the year.

For the continental United States, these constellations include most or all of Cassiopeia, Cepheus, Camelopardalis, Draco, and the two Bears: Ursa Major and Ursa Minor.

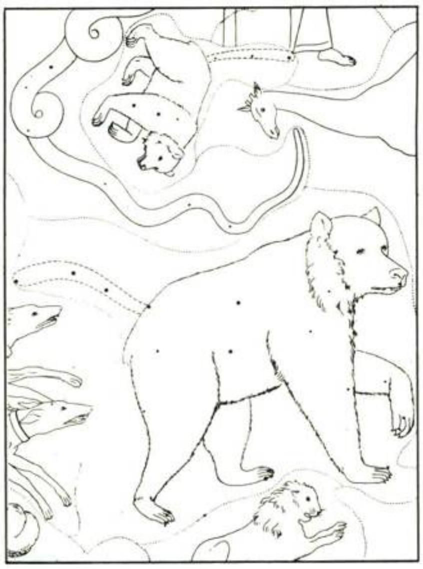
The two Bears, of course, are better known to us as the Big Dipper and the Little Dipper. The Big Dipper easily wins the competition with Orion for the title of the best known asterism, or grouping of stars, in the sky. As it is formed from only part of the constellation Ursa Major, the Big Dipper is not actually a constellation in its own right. In fact, it is for most people today the *only* recognizable stellar formation — provided they know where to look for it. In England it is known differently, as either the Plough or the Wain (wagon), sometimes Charles's Wain. What we see as the bowl of the dipper becomes a wagon, with the three handle stars representing three horses in tandem.

But it is as bears that nearly all cultures, ancient and modern, have seen these two circumpolar constellations. In a way, that's surprising, since no bear known is possessed of such a long, graceful tail as these two heavenly ones. Many of the tales associated with the Ursae incorporate an explanation for this. The most obvious explanation, of course, is the most common, expressed amusingly in the classic words of the seventeenth century astronomer Thomas Hood: "Imagine that Jupiter, fearing to come too nigh unto her Teeth, layde holde on her *Tayle*, and thereby drewe her up into the Heaven; so that shee of herself being very *weightie*, and the Distance from the Earth to the Heavens very *great*, there was great likelihood that her Taile must stretch. Other reason know I none."

In proportion, the tail of the Small Bear is even longer than that of the Great. Perhaps this is because of the continual strain of being swung around the pole, for the Small Bear has the end of her tail nailed, as it were, to the pole.

The American Indians, however, had another, more clever way of dealing with the superfluous tail stars of Ursa Major. In astronomical terms, these three stars are "following" the others; that is, as the Earth rotates under the sky, they cross the meridian after the rest of the constellation because they lie farther to the east. Picking up on this, the Indians saw the three as hunters in pursuit of the bear, chasing her eternally around and around the pole. And what of Mizar and Alcor, the double star in the middle? Why, that hunter (Mizar) is carrying a pot (Alcor) in which to cook the bear once it has been slain!

The Housatonic Indians of New England carried the story further and accounted for the profusion of brilliant autumn colors for which New England is famed. According to them, the hunt reaches its climax in the early fall, when the lead hunter thinks he has finally gotten close enough to the bear to try a shot at her with his bow and arrow. It is at that time of the year when Ursa Major sinks down closest to the northern horizon during the midnight hours. While his shot fails to slay the great bear, she is deeply wounded, and her blood, dripping down to Earth in great drops, stains and colors the leaves of the trees. And indeed, the colors of autumn spread down over the land from the north like a great flow of blood from the wounded bear lying on the northern horizon.



How did the bears get into the heavens in the first place? According to the ancient Greeks, the Great Bear was once Callistro, a beautiful maiden. Jupiter, who had quite a penchant for beautiful maidens, managed to make an arrangement with Callistro behind his wife Juno's back. Juno, being a goddess, found out what was going on, and changed Callistro into a bear for punishment. Callistro's son by Jupiter, named Arcas, had already been born, and grew up to be a renowned hunter. Years later he spotted a bear in the woods and took aim with his bow and arrow. The bear, of course, was his mother, and Jupiter saved them by changing Arcas into a bear and placing both in the heavens.

Juno still managed to get her revenge, though, because she went to Neptune, the god of the seas, and talked him into forbidding the two bears from bathing in the waters of the ocean. Instead, they were condemned to circle endlessly in the sky without rest or refreshment.

So if you buy this tall tail — uh, *tale* — you know why Ursa Major and Ursa Minor are circumpolar constellations.

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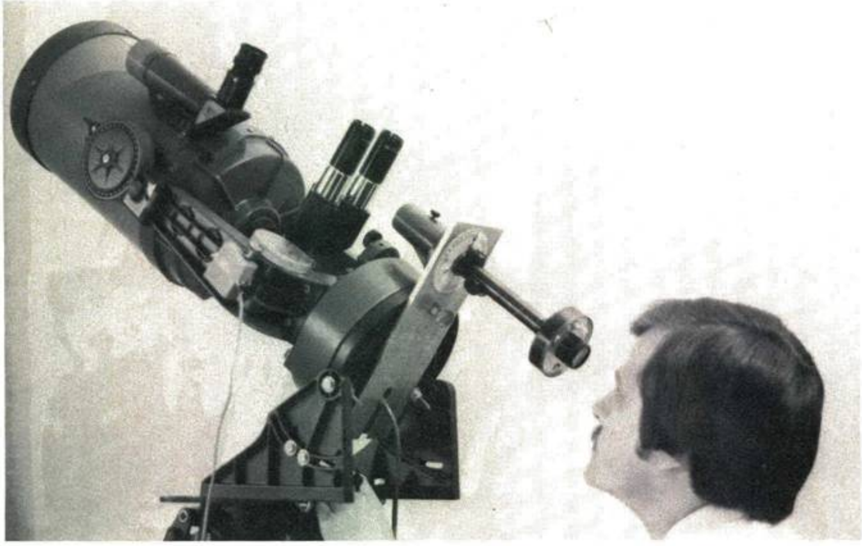

by
Kerry D. Martin
3013 Apollo Rd
Garland, TX 75040

Shown aligning his Celestron 8 with the Celestial Polar Axis Finder

Kerry says:

"The Tuthill Precision Polar Axis Finder is a specially modified gunsight which lets me see Polaris on the .8 degree offset cross-hairs while it mechanically points to the Celestial Pole. Thus permitting me to move the scope in azimuth and elevation using the companion Polaris Pointer wedge device. As a result the polar axis of the C-8 is exactly lined up equatorially without leveling the tripod or even knowing my latitude!!

I have exhaustively tested the Precision Polar Axis Finder; its theory of operation, its stand-alone measurements of its angular offset accuracy and its practicality for use on my Celestron 8. My detailed measurements showed the Precision Finder to be extremely accurate — in fact I believe its accuracy is limited by only the width of the fine reticle crosshairs. With such accuracy, theory predicts that an exact polar alignment is more achievable than the time consuming "drift method". Furthermore it is not dependent upon the Dec circle being accurate or lined up as methods that used offset telescope finder reticle crosshairs. Because the Precision Finder is so easy to use it enables me to get precise polar alignment in under 5 minutes. I have double-checked the alignment several times on different occasions using the "drift method" and find the initial alignment is virtually perfect. This ingenious device has saved me countless hours, which were spent observing instead of aligning!

My Celestron 8 is also fitted with a Tuthill 50mm right angle Rich Field finder. It features easy collimation with only 2 finger-tip adjusting screws, gives a bright wide field, interchangeable 1¼" eyepieces and a built in dew cap. It is the best finder I have ever used on my C-8. Tuthill's Micro Drive, slow motion, R.A. attachment and the Red Setting Circle lights are great additions, too.

There is nothing like my Stereoocular for a binocular close-up real life feeling of three dimensions of the Moon, Sun or planets. It makes me feel like I am in orbit. The field of view seems to expand and it is very relaxing to view with two eyes at once. I agree with Arthur Clarke — the views are mind boggling."

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totality

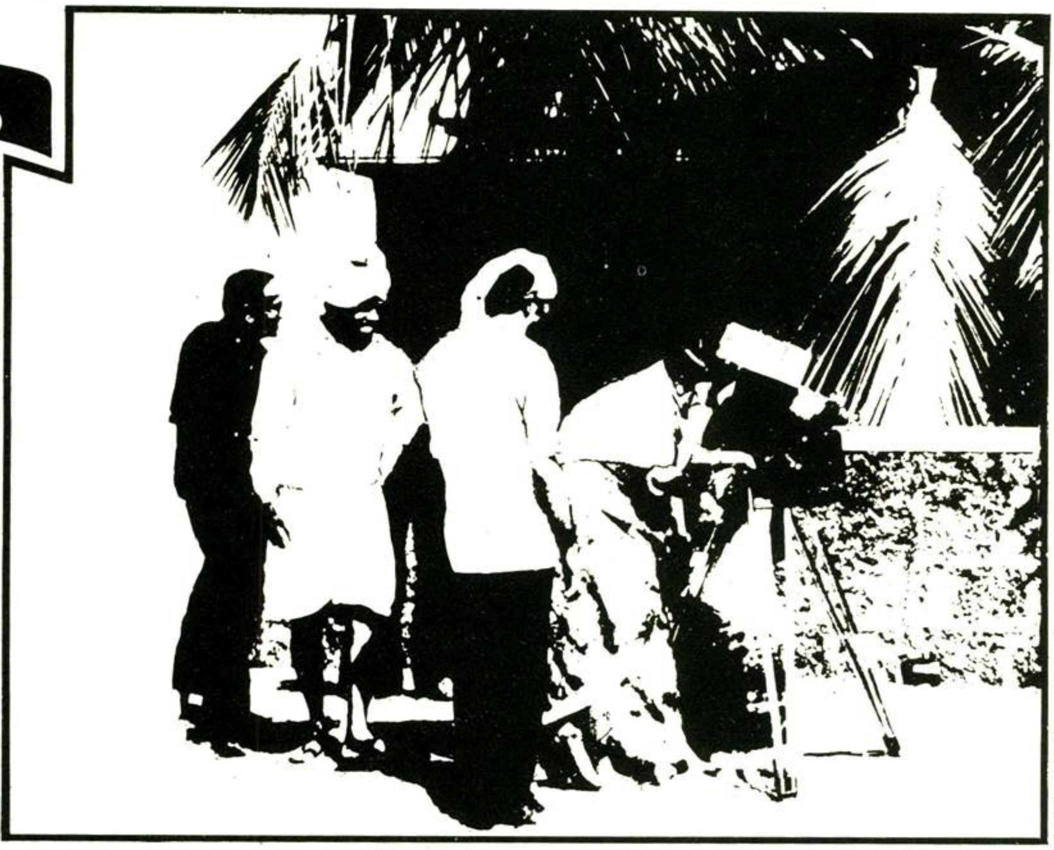


photo by Jorge Alberto Soto

"Simply exquisite!" "Utterly stunning!" "As perfect as you could wish for." "The most beautiful of recent eclipses...."

And so it went, as letter after letter came pouring in to ASTRONOMY. Every correspondent, it seems, had a successful expedition and has returned home laden with remembrances. Despite some last-minute worries about clouds among the African-based groups, it appears that most everyone who went saw the sights and nabbed the photographs they'd come thousands of miles for.

And truly, it *was* a fine eclipse. In some respects similar to last February's North American eclipse, this year's Afro-Indian eclipse also came at a period in the sunspot cycle when the activity was near its peak.

The shape of the corona depends greatly on the state of sunspot activity. In years of low activity, the corona extends outward primarily from the Sun's equatorial regions, with only short spiky streamers at the poles.

But as the solar activity increases, the pearly corona grows to surround the solar disk evenly. The 11-year cycle reaches its peak this year, and many observers noted how symmetrically the streamers and plumes stretched out to 3 solar diameters or more in a beautiful ring. The corona displayed some surprising features in the eclipse — including a seldom-seen coronal knot.

The February 1979 eclipse, seen across Canada and the northwestern states, featured some very striking prominences — gigantic gouts of gas thrown far out from the Sun's photosphere. Those seen this year weren't so striking, but as the photos last month and those in the pages to follow show, they left little to be desired.

One of the curious sidelights of every total solar eclipse is the reaction of the local inhabitants, human and animal, to the unusual events unfolding above. Aside from whatever reaction is caused by the eclipse itself, cultural shock (on both sides!) often ensues when hordes of foreigners bearing weird equipment suddenly descend in hundreds or even thousands on one small area.

In India, one writer noted that "as usual, the newspapers continue to use scare tactics concerning solar viewing," and bemoaned how often this happens back here, too. He and his friends were able to show the villagers how to observe safely — the male ones, that is. The women wouldn't look through the telescopes and went inside during totality. "Superstition ran deep," he concluded.

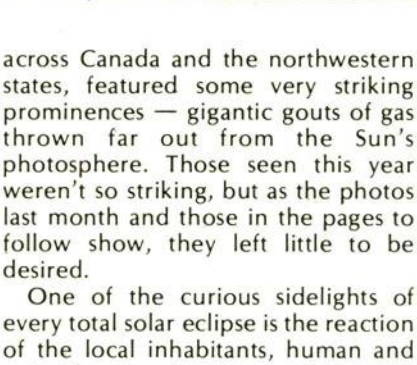
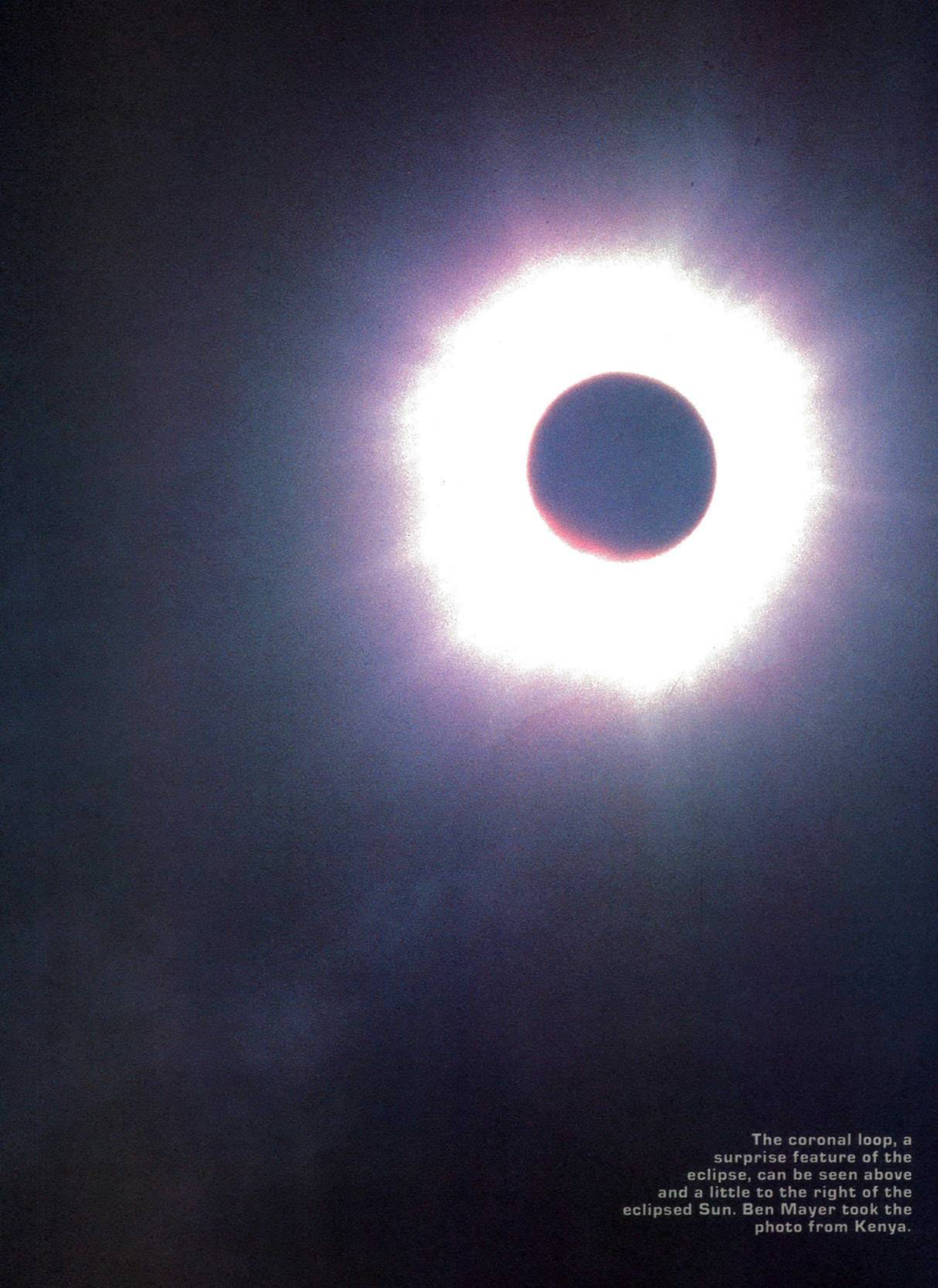


photo by Rick Dilsizian

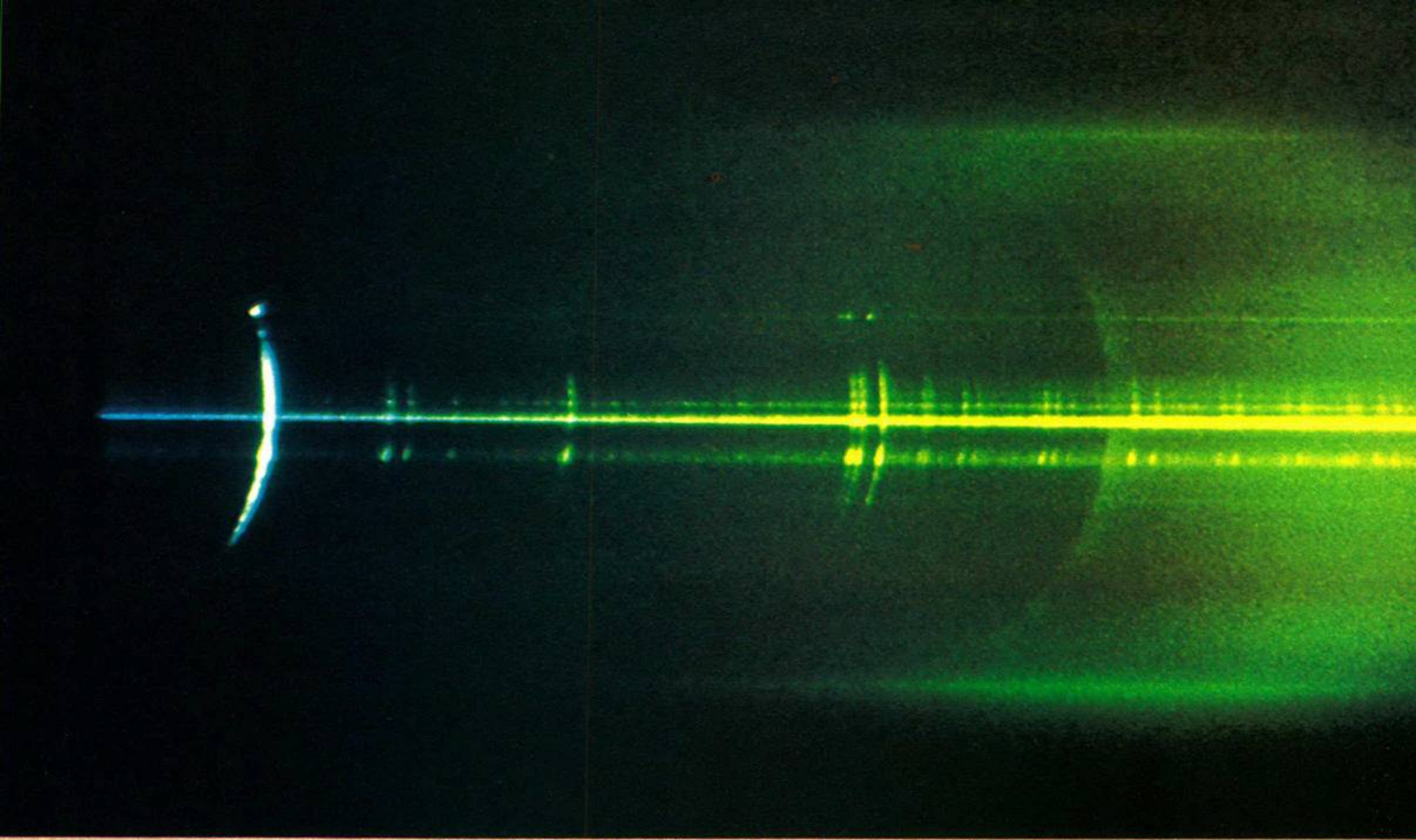
Farther east, where the eclipse took place later in the day, Chinese onlookers were shown how to observe the partial phases by using projection methods (with binoculars or a pinhole), exposed film, or by viewing the Sun's reflection in a pan of still water.

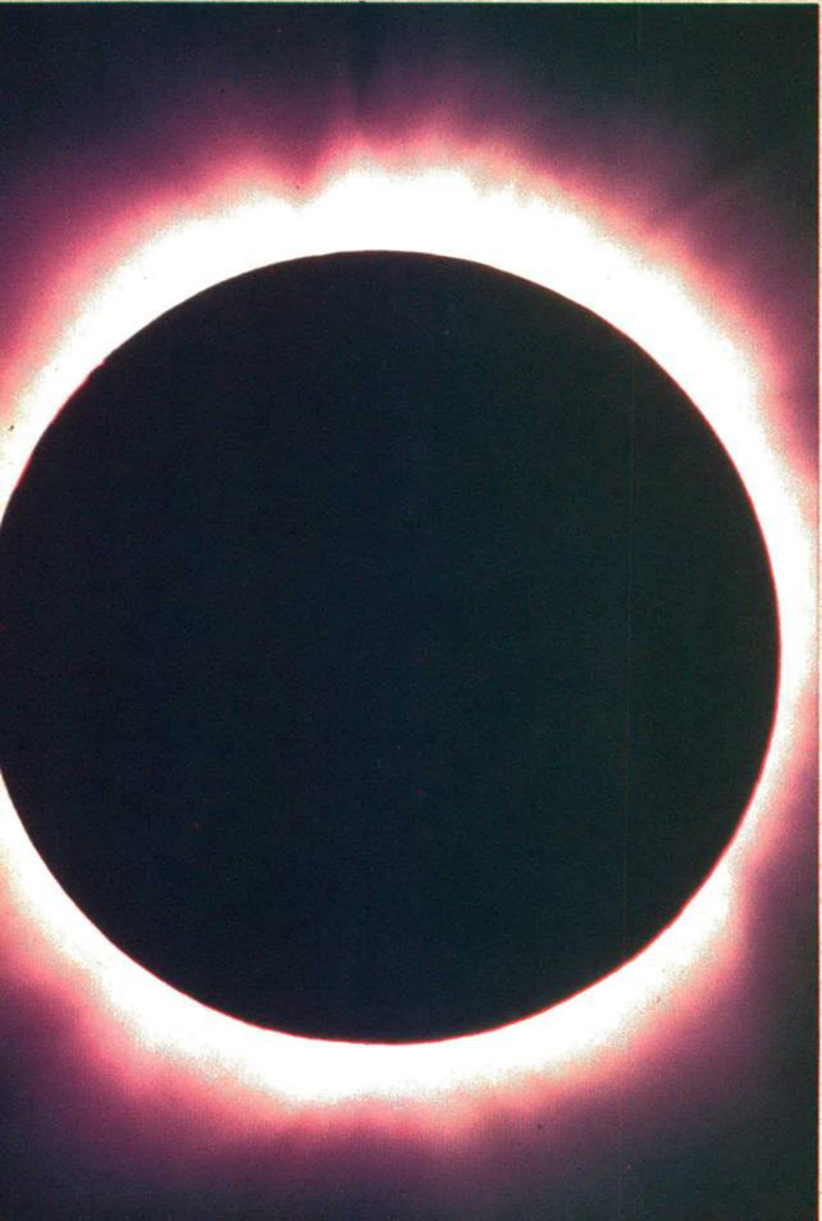
Astrologers in India had predicted the event would bring on all sorts of dire consequences, but according to the *Sunday Navhind Times* of Panjim, Goa, none were noted. The same source also mentioned that careful observation of mental patients and zoo animals revealed no abnormal behavior!

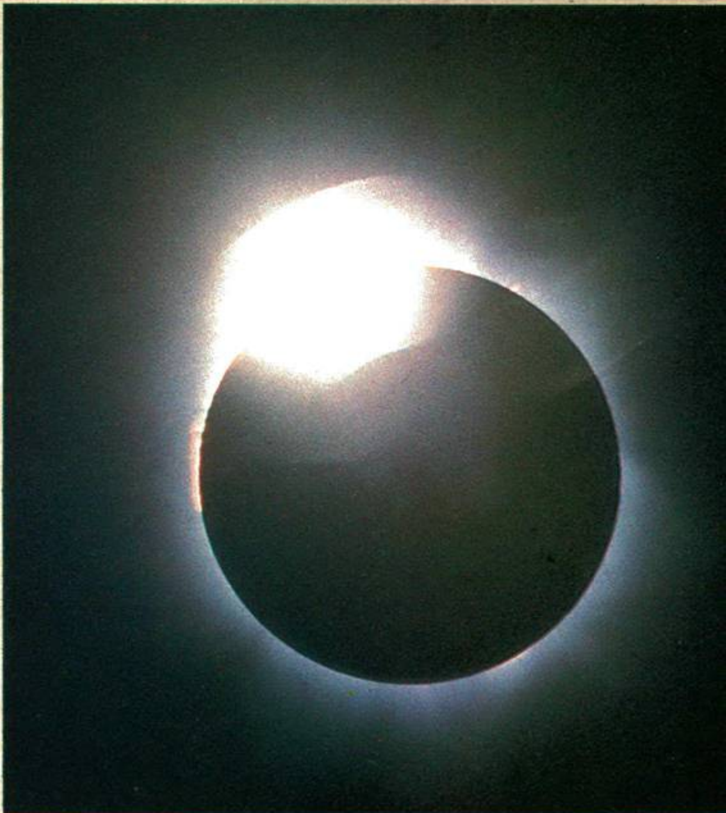
The slow onset of darkness during the partial phases in part mimics the growing dusk in a natural sunset, and so wild animals usually commence their nightly routines as totality approaches. An observer in India noted that about 15 minutes before totality, "a dozen noisy ravens began to circle us at low altitude." Ten minutes later they flew away. In Kenya, a nearby herd of some 30 grazing



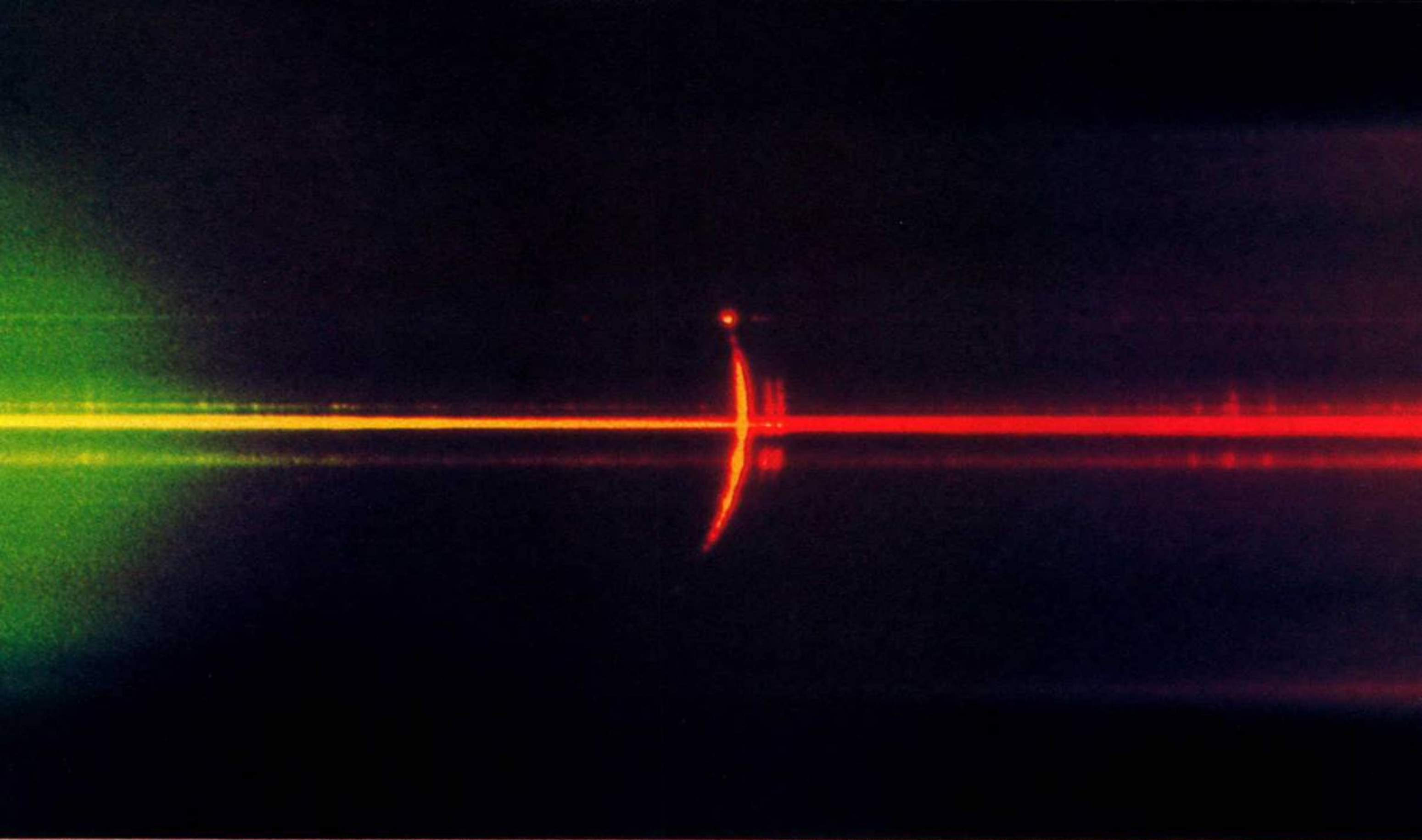
The coronal loop, a surprise feature of the eclipse, can be seen above and a little to the right of the eclipsed Sun. Ben Mayer took the photo from Kenya.

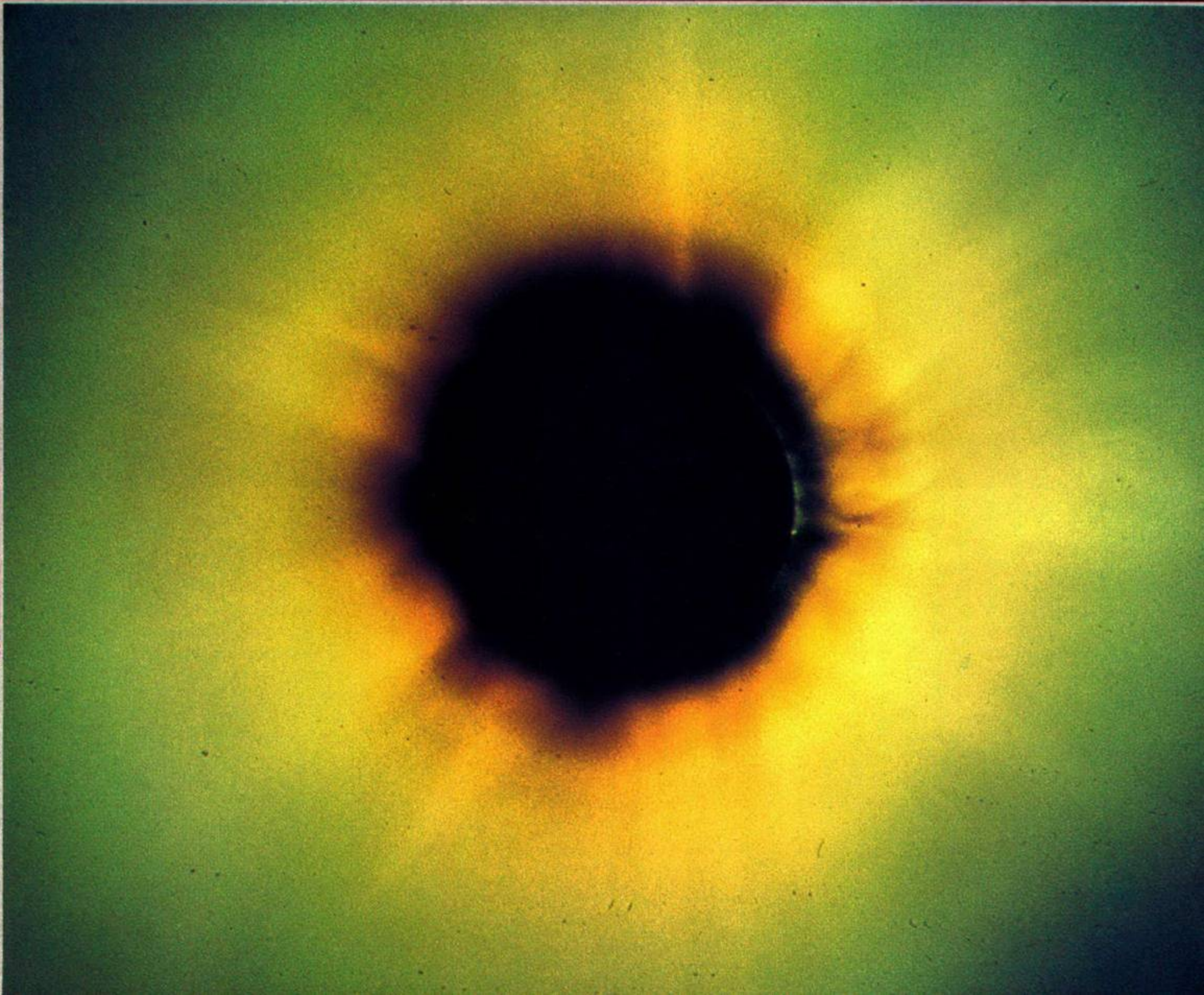


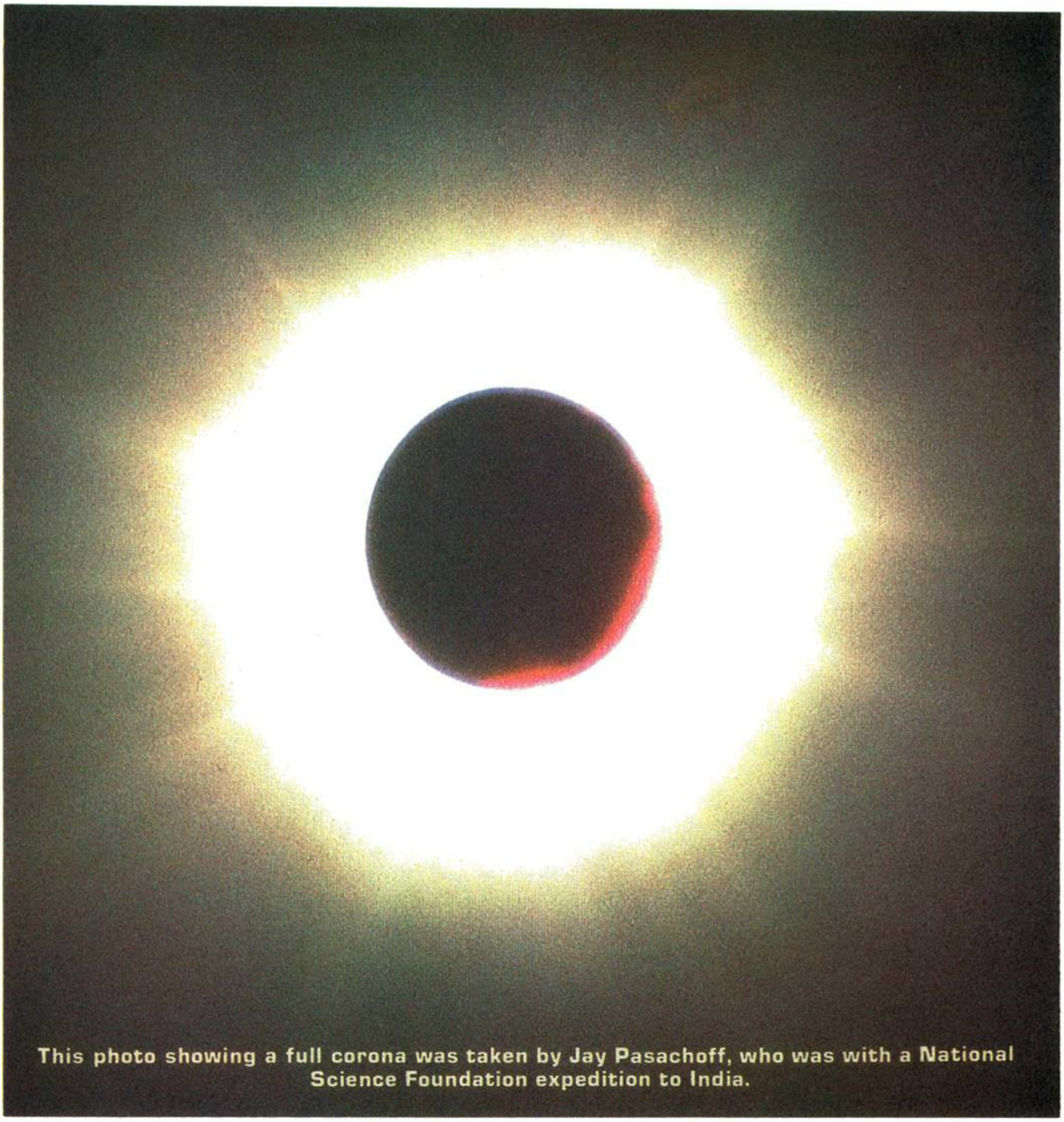




Across top: Ernest Piini made this flash spectrum shot from Taita Hills, Kenya. Left: This photo showing the inner corona was taken by the "Tsavo East Solar Eclipse Expedition." Above: The diamond ring at the beginning of totality was photographed by Hansen Planetarium's Patrick Wiggins near Voi, Kenya. Right: Infrared film and a variable-gradient filter helped Ernest Piini nab this photo showing streamers extending far out from the Sun's disk.







This photo showing a full corona was taken by Jay Pasachoff, who was with a National Science Foundation expedition to India.

impala ceased their activity as totality approached and bedded down when it arrived.

Just what environmental clues they are responding to isn't always clear: decreased light levels, freshening winds, dropping temperatures, and others, probably all contribute.

At Ankola, India, on the ocean, the air temperature dropped from 95° F when the eclipse began at first contact to 68° F during totality. In the same location, another eclipse viewer estimated the ground temperature plummeted 40° F — from 125° to 85°.

Most people spent totality either gazing up into the sky or, almost as often, into camera viewfinders. But even the most avid camera bugs managed to spare a glance for their surroundings, and when they did, they were greeted by a dim yellowish half-light all around the horizon, caused by sunlight outside the zone of totality. The sky itself overhead seemed deep indigo with the Sun and corona "looking like a daisy," flanked by Mercury and Venus.

Shadow bands, those perennial features of solar eclipses, were noticed by some people but not others. The diamond ring, caused by sunlight streaming through valleys on the Moon's limb — lasting "forever" to some people, 5 or 10 seconds to others — heralded the beginning and end of totality.

As the pleasures of eclipse-chasing become more and more popular, tours set out and group expeditions organize. The past 10 years have seen a great increase in the numbers of people going off to corners of the world for a brief look at nature's most splendid event.

The future — with increasing fuel shortages and transportation costs — no one can foresee. But whatever the outcome, no one who's been to an *eclipse comes away unaffected* — and that will never change.

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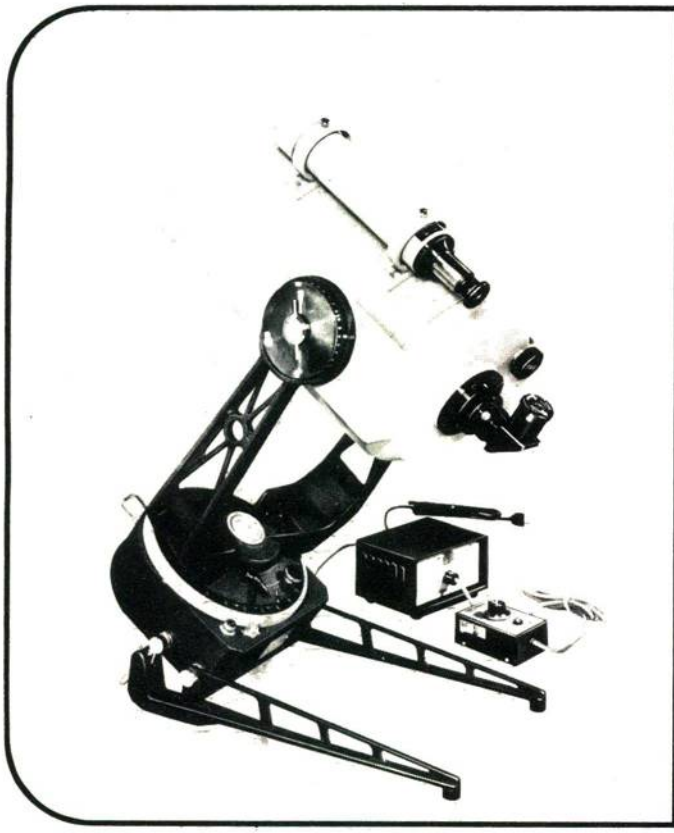

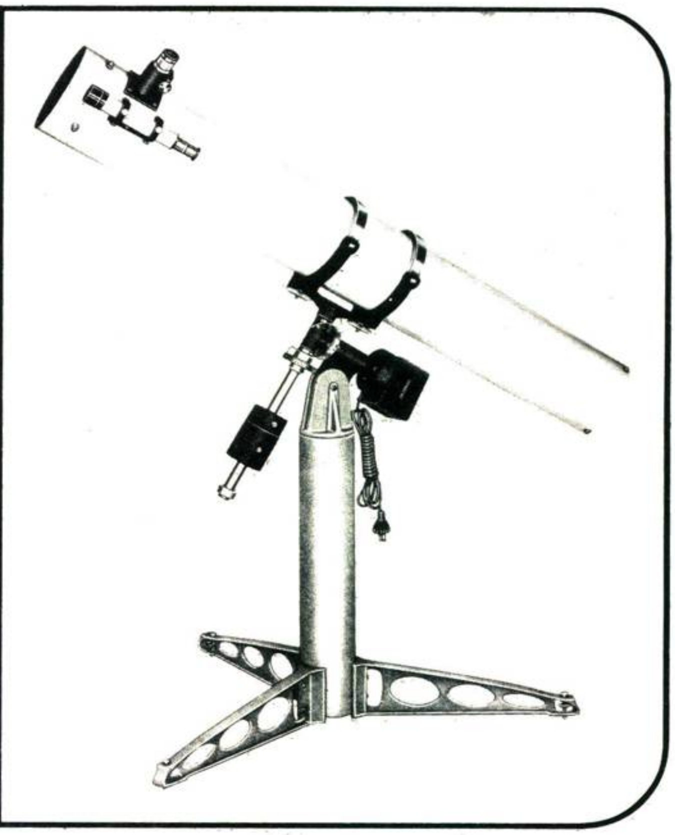

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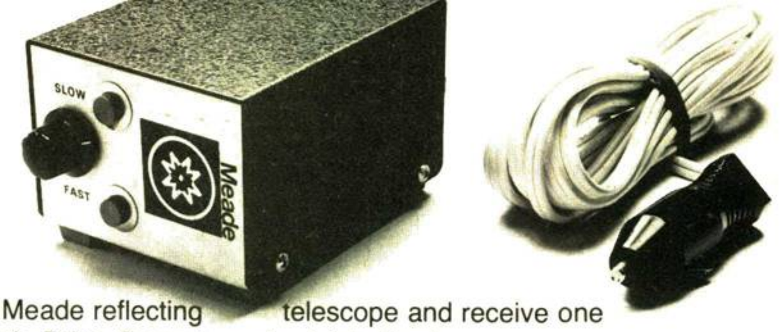

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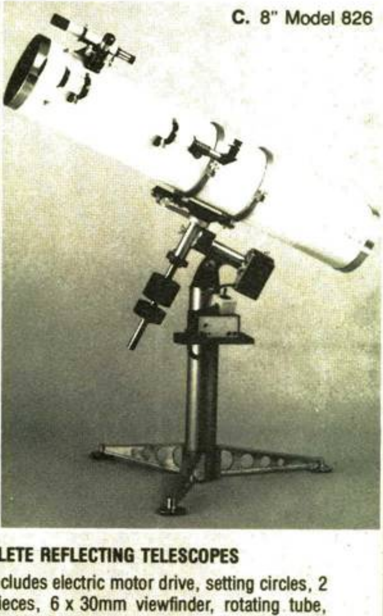

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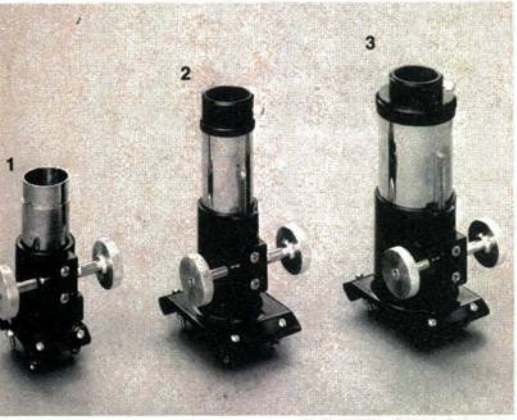

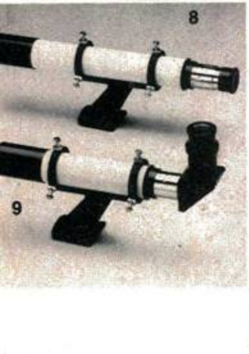

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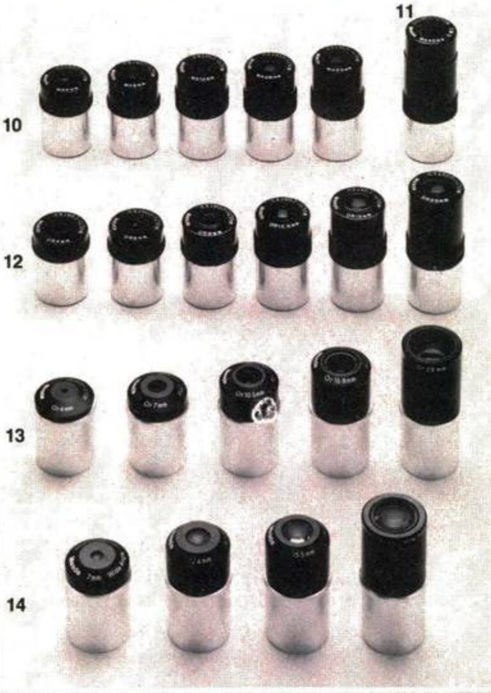

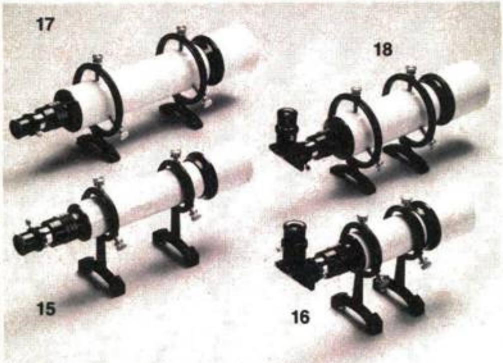

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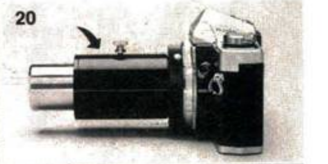

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gazer's
gazette

watching the lunar phases

Have you ever noticed the love/hate thing astronomy enthusiasts have with the Moon? You know, it's lovely to look at, with loads of landforms — craters, mountains, rilles, etc. — all easy to find and fun to explore.

But there's also the other side of it: From first quarter through full to last quarter, there that foolish thing sits, flooding out nebulae and washing away galaxies with its light.

Most people begin their telescopic skygazing with the Moon. For a while, they wander vicariously over its roughhewn surface seeking out its fascinating complexities. But unless the "lunar bug" bites deep, they find that as time passes, their observational interests shift, perhaps toward deep-sky objects. And if they do, that initial fond regard for the Moon will soon change into dull, grudging acceptance of a light-blitzed fate, replete with curses muttered through clenched teeth.... Sound familiar? Well, hold on — you're missing the forest for the knobs on the bark!

Step back and take a longer, less partisan view of things. You're forgetting that besides its manifest telescopic allure and despite its infamous role as Chief Obliterator of the Nebulae, that "orbed maiden, with white fire laden" (in Shelley's words) is quite simply one of the grandest sights in the sky — even if your only equipment is your two eyes.

Think about it. Where else could you see such a fine example of heavenly clockwork? Or as many different sights in one celestial body? And all of this is laid out for anyone curious enough to spend a few weeks doing some plain ol' looking.

Of Moons and Magnitudes

The story is told of a schoolboy who was stumped on a test by the question "Which is more important, the Sun or Moon?" — and who answered "The Moon, because it shines at night when the Sun isn't up."

Nonsense? Of course, but it suits most people's intuitive feelings. A full moon certainly seems bright — after all, it's enough for many to read by — but in actuality, the Moon is a very poor mirror. It reflects only 7% of the sunlight falling on it: roughly the same as a weathered patch of asphalt pavement.

Your very adaptable eyes are fooling you: The full moon lags far behind the Sun in brightness — by 14 magnitudes to be exact. If you're unfamiliar with magnitudes, 14 of them may not sound like much, but it represents a whopping difference in brightness: nearly 400,000 times.

Even weirder is the way the Moon's brightness changes during the month. You might expect that the quarter phases (first and last) would be half as bright as full, but it isn't so. To see for yourself, let's follow the brightness changes from new moon to full moon.

When the Moon first reappears in the evening sky after new moon, it's a slender, dim "fingernail" crescent low in the west. For the first day or two you may miss it altogether in the twilight unless you are careful.

Three or four days after new, it's clearly visible even before the Sun has set, the crescent looming wider and brighter. By the time first quarter rolls around, the hide 'n' seek is over — you'll probably spot it during the afternoon, and after sunset, it begins to cast shadows onto light-colored surfaces.

The surprise comes between first quarter and full when the brightness increases very quickly — you'll discover that the full moon is ten times brighter than either quarter phase. Astronomers call this surge of brightness an *opposition effect*, and it tells them something about the fine structure of the Moon's surface layers.

When you observe the Moon at its quarter phases, sunlight is falling on the porous, rocky rubble of its surface at right angles to your line of sight. If you could examine the surface at close range, you'd discover that a lot of the lighted hemisphere, in fact, is in shadow.

The small shadowy crevasses are too small to resolve individually — even in the largest telescopes — but have the cumulative effect of lessening the Moon's overall apparent brightness. But as the phase draws closer to full, the direction of sunlight and your line of sight become more and more nearly the same. Relatively abruptly, your gaze falls on not only the most superficial lighted layer, but all the illuminated bottoms of the little pits, too. Every object stands in front of its own shadow. In effect, the area of visible, sunlit Moon has increased many times.

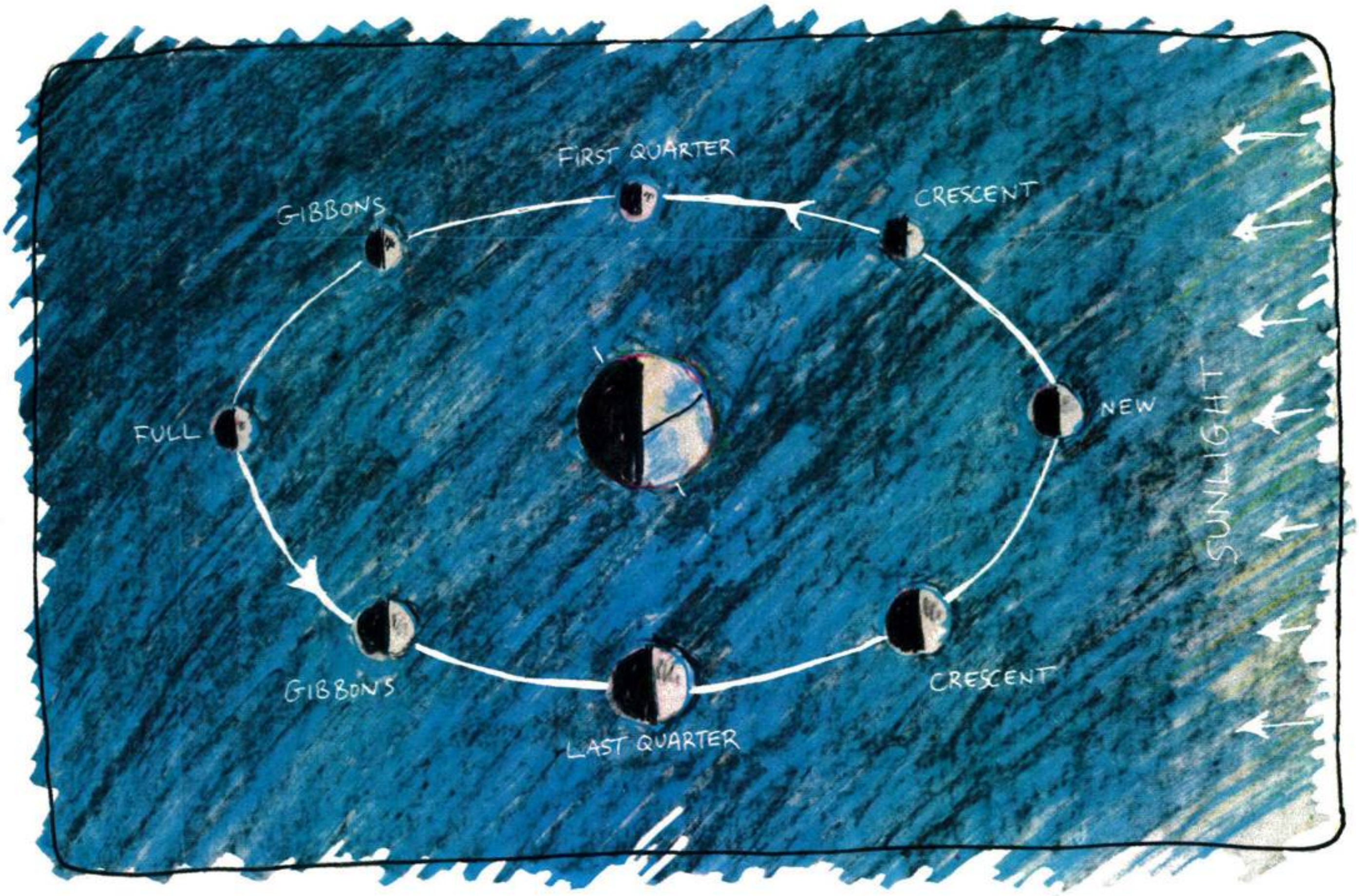
The "Youngest Moon" Sweepstakes

When you were looking for the crescent "new" moon to see how bright it was, you probably found it at least a day or more after new — and it wasn't too easy to find even then. Now, for 60 zillion dollars, how soon after new moon can you find a thin crescent in the sunset sky? Or, for that matter, how late in the lunar cycle can you still glimpse a Moon in the dawn sky?

This is one of those crazy "contests" that add fun, spice, and a little competition (even if only with yourself) to observing.

Many claims have been made — often unwitnessed and thereby suspect — but very few are for less than 24 hours after new moon. The unofficial world's record (set in 1912) is 14 hours. Can you beat it? Start by looking up the date and time of new moon in each month's Through the Eyepiece and give it a go.

While you're outside peering at thin crescent moons, take a moment to observe "the old moon in the new moon's arms," a phenomenon otherwise known as *earthlight*. This is



the ghostly grey part of the Moon inside the horns of the illuminated crescent. It is sunlight twice reflected: first, off the Earth's clouds and oceans out to the Moon, and then off the Moon's dusty rocks back to Earth.

Before first quarter, earthlight is easy to see, but as the lit part fills out, it gets harder and harder to find. With a telescope, it's visible up until a few days before full, but how long can you follow it with just your naked eye?

The Moon in June...

Everyone's heard of the Harvest Moon (the full moon nearest the equinox in September) and a few other people may have heard of the Hunter's Moon (which comes a month later), but were you aware that each and every full moon in the year has a popular name or two? Many of the "Farmer's Almanacs" list them for each month throughout the year.

January, for instance, is the Old Moon or the Moon after Yule. February's is the Wolf or the Hunger Moon. March has the Sap or Crow Moon, while April gets the Egg or Grass Moon. The Planting Moon comes in May, and the Rose or Flower Moon in June. July's is called the Thunder or Hay Moon. August has the Grain or Green Corn Moon, while September and October have the Harvest and Hunter's Moons, respectively. The year finishes off with the Frosty or Beaver Moon in November and the Long Night Moon in December.

The one hitch in all this is that there are more full moons in a year than months, since the lunar month is shorter than the average calendar month. Accordingly, these moons may come early or late in the months indicated — and some months will have a second full moon. The one benchmark in the cycle seems to be the well-known Harvest Moon in the fall, but since the names are just folklore anyway, there's no great concern if you want to let them wander around a bit in the year.

The Moon Illusion

Folklore or not, there's one name every full moon could have: the "Big-Cookie-in-the-Sky" Moon, at least to judge by its appearance low in the east at sunset. Just why the rising full moon looks so abnormally large — the so-called *moon illusion* — is a puzzle that has kept theorizers, amateur and professional, busy for the last couple thousand years.

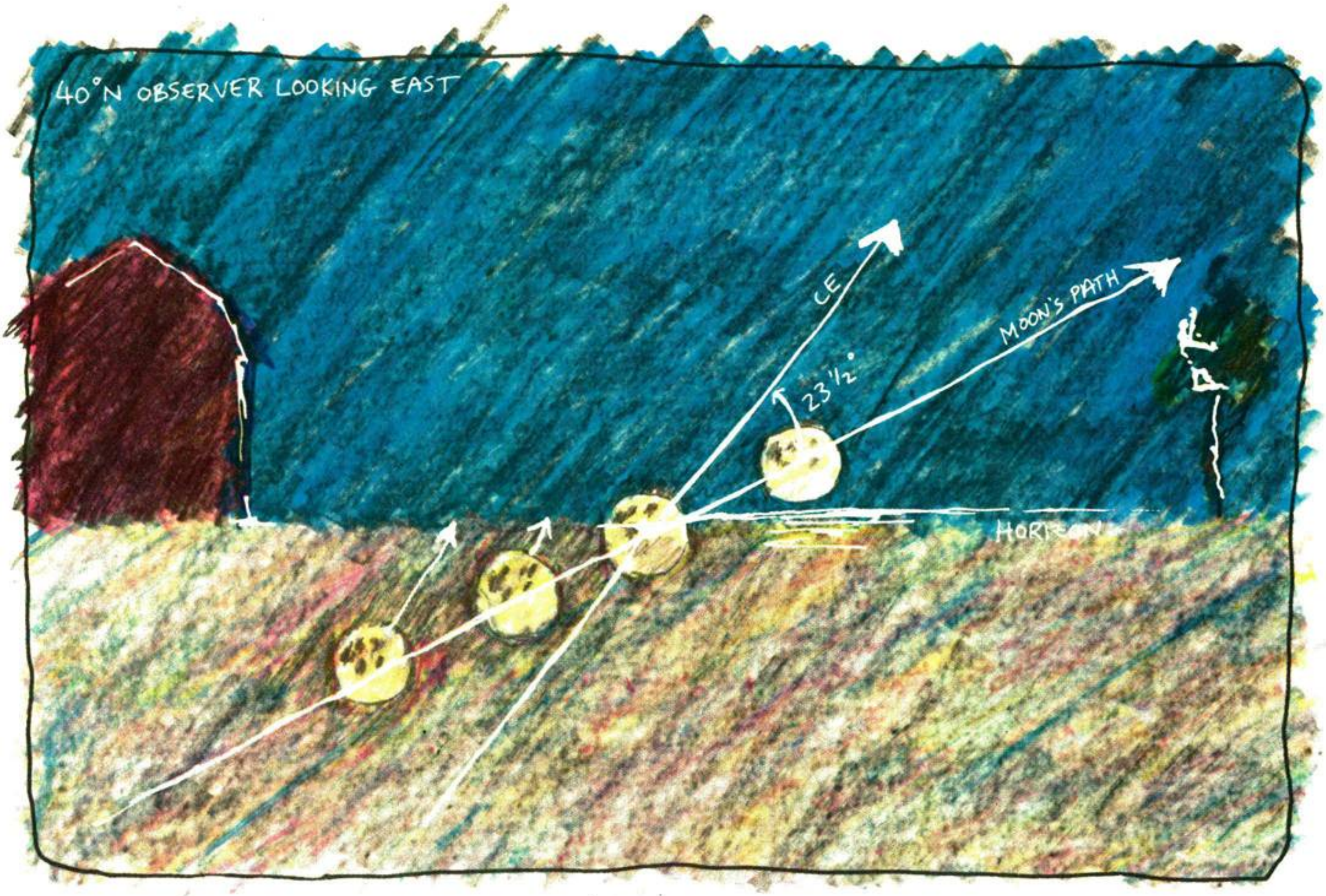
But strong as the impression is, it's only an illusion. In fact, the Moon subtends a slightly bigger angle when it lies on the meridian than when rising or setting. Why? When it's on your meridian, you are about one Earth radius (4000 miles) closer to it than at the time of rise or set.

The illusion is undeniably startling, however, and it's curious that no one has a really satisfactory theory to explain it. Some of the more interesting ones have postulated a magnification effect in our atmosphere (but the magnification isn't enough), or something in the way you hold your head when looking at the horizon as opposed to up into the sky (experiments shot this one down), or even the fact that the open sky lacks angular-size clues like distant houses and trees (this may be the best guess so far). Since there is no physical effect at all, the eventual explanation will likely come from a psychologist.

Push Your Eyes to Their Limit

Gazing on the Moon, you will immediately notice some light-colored patches and some dark ones — these gave rise long ago to "the Man in the Moon" and the other figures seen by various cultures. With the help of a little telescopic foreknowledge, it's fun to see just how much lunar "topography" you can make out with your naked eye. It'll be more than you think.

To start with, go out in late evening on a night near full moon and really examine its disk. Visualizing the Moon's disk as a clock face, at about 2 o'clock you'll see the little dark spot of Mare Crisium. Originating at the bottom (7 o'clock, say), there's the bright splash of rays from Tycho which extend across much of the Moon's earthside hemisphere. The Man in the Moon's right eye is Mare Imbrium, a vast plain of basalt oozed out of the Moon's interior eons ago. His left eye



is Mare Serenitatis, another dark basaltic expanse. His nose and mouth are formed by several other maria, all lava flood plains.

Sharp eyesight will pick out bright spots here and there — especially the crater Aristarchus at about 10 o'clock on the Moon's face. These are fresh impact craters and their associated splash patterns of rays. (In some ways, the naked eye is best for doing a rough sorting of lunar terrain into types.)

When you've practiced on the full moon, try some of the other phases. First quarter reveals Mare Crisium, of course, and the dark patches of Maria Serenitatis, Tranquillitatis, Nectaris, and Fecunditatis. About 5 hours after first quarter, the Sun is rising on a chain of craters in the lower middle of the Moon's disk. Among the many littler craters are three large ones — Ptolemaeus, Alphonsus, and Arzachel. People with excellent vision should be able to discern the slight irregularity in the sunrise terminator caused by this north-south trending chain of craters.

At last quarter, the most prominent features are Mare Imbrium and the dark expanse of Oceanus Procellarum to the south and west. Tycho and his rays are gone, being features visible only around full, though Aristarchus remains relatively bright. The dark patch at about 8 o'clock is Mare Humorum.

The Moon's Orbit

So far we've looked on the Moon as an object; let's pull back our perspective and examine its motions. The path it follows around the Earth isn't a perfect circle; no orbit ever is. Instead, its elliptical circuit brings it alternately closer and farther away from us. The points of farthest and closest distance are called *apogee* and *perigee*, respectively.

The orbital ellipticity is such that the Moon's apparent size varies between a maximum of 32'48" and 29'23" — about half a degree on average. The difference is theoretically discernible by eye, but very difficult to make out without a measuring device.

You may already have noticed that in summer, when the Sun moves high through the sky, the full moon stays relatively low and, conversely, how in winter with a low Sun, the full moon blazes down from almost overhead.

What's happening is that the Moon is following the *ecliptic* — the path in the sky that the Sun takes — almost exactly. At full, for example, when it's on the opposite side of the sky from the Sun, the Moon is at low declinations (if the season is summer) and at high declinations (if it's winter).

But although the Moon stays close to the ecliptic, it isn't exactly on it; it's inclined at an average of a little over 5°. The effects of this are far-reaching as we'll see in a moment.

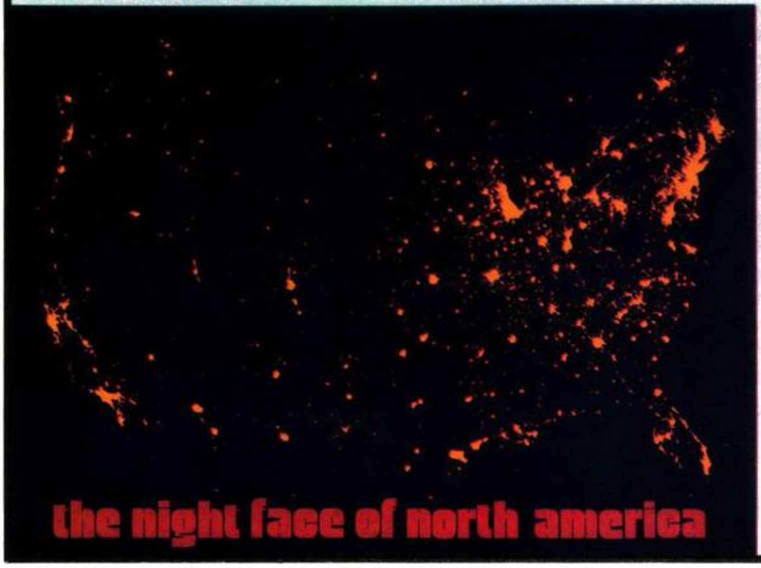
Because the lunar orbit is at an angle to the ecliptic, it has to cross it in two places. These points are called the *nodes*; there's an ascending one (when the Moon crosses the ecliptic from south to north) and a descending one (moving north to south). So what, you ask?

Well, if the Moon's orbit lay precisely on the ecliptic, then you'd see a solar eclipse at every new moon and a lunar one at each full moon. But the lunar orbit is tilted and so the Moon lies on the ecliptic only when it passes through the nodal points. If the nodal crossing comes at full moon or new moon, you'll get an eclipse. Since this doesn't happen very often, most of the time the Moon passes above or below the Earth-Sun line.

The most remarkable thing about watching the Moon in its ceaseless swing around the Earth is how early many of its complexities were discovered. The essentials of lunar motion were well-described by the time of the Greeks. For whatever their reasons, the ancients observed and understood (if only in an empirical way) a surprisingly large amount. We, in our turn, inherited this and have added immensely to it.

All the same, it's quietly satisfying to stand and look out into the night at our satellite, knowing, understanding, and remembering that you are part of a human tradition practiced for as long as people have been people. — *Robert Burnham*

The Night Face of North America



When we printed this stunning image in January 1980, we didn't expect such an intense reader demand for a reprint. So here it is, shining against the darkness of night, the outline of our continent as defined by millions of lights marking the location of human activity and energy consumption. If your home town has over 5,000 population you should be able to locate it.

NEW FROM ASTRONOMY

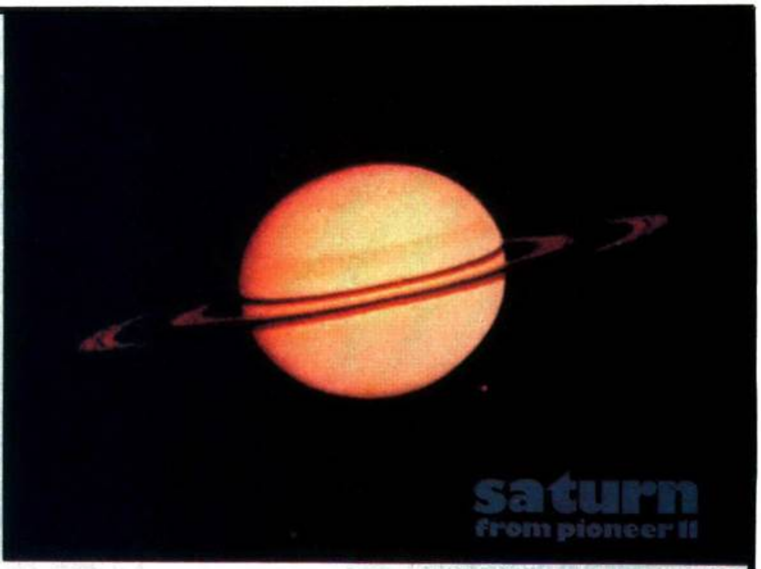
Full color 17x22" posters, rolled in a tube and ready for your wall

to order use form between pages 60-61

$2.95

Saturn By Pioneer

The best image from the recent fly-by, showing the subtle colorations of the planet along with the flowing rings and their shadow, and tiny Rhea drifting in the foreground. The lighting of the rings gives a view never seen from Earth, and the entire enhanced image presents a strikingly different view of the solar system's loveliest member.



ASTRONOMY
IN FOCUS

Techno-Messianic

Sir / As I am a fairly reasonable individual, I was content to allow my participation in the SPS controversy to rest with my now-infamous comment about "techno-messianic zealots." But sloppy dealings with reality annoy me, and since my choice of words is being bandied about, seemingly at second and even third hand, I feel that I must return to the tiresome business.

If David J. Ulrich will kindly read my letter in the November 1979 In Focus, he will find that at no time did I ever say anything about raping and plundering the universe. What is uppermost in his own thoughts is his business. I happen to be concerned with the quality of life on my homeworld. Indeed, as a woman, rape is not something I take kindly to.

Onward. If anyone will take the time to look at the derivation of my silver-tongued phrase (do I have to tell these people everything?) he or she will find that it was chosen with not a little deliberation. Techno: pertaining to technology. Not bad for a concept like the SPS which deals with a couple of trillion dollars worth of hardware hoisted into stationary orbit and used to transform and transmit raw energy. Messianic: pertaining to a savior or deliverer. In this particular case, technology is the messiah, dropping kilowatts on our doorsteps instead of sanctifying grace into our hearts, solving all our problems by ushering in the Kingdom of Plenteous Energy. Zealots: what better term for people who believe that if the rest of us don't like what they want, they'll shove it down our throats anyway.

About Earth: It's a nice place. I happen to live here. If my next-door neighbor decided to dig a swimming pool in my backyard for his personal use, I would get somewhat annoyed. In the same way — all trivializations such as "insignificant planet of an ordinary star" aside — if someone wants to turn my world into a toilet simply to insure a power supply for his Cuisinart, I will get frighteningly angry and churn out "ad hominem" phrases like "techno-messianic zealots." It's my only defense.

And lest certain individuals shake their heads and brand me a cosmic isolationist, or even a planetary chauvinist, let me go on record with the following: I like stars, planets, comets, galaxies, and the whole lot. I would like to find out what they are and why. I support NASA's efforts to get a probe out to comets Halley and Tempel 2. I was glued to the TV when the Jupiter pictures came in. Ditto Mars. I was nailed there when we landed on the Moon. All this does not mean, however, that I am willing to sacrifice my homeworld for the naive and egotistical thrill of perceiving my civilization as "higher" or "more advanced" than someone else's. This is locker-room tomfoolery and I want no part of it.

Besides, I said in my original letter that I'd back SPS, so what's Ulrich's beef?

Gael Baudino
Los Angeles, CA

Fireball

Sir / I am an airline pilot and observed an especially bright meteor on January 16 at about 7:20 p.m. MST.

We were departing Denver eastbound, climbing through 25,000 feet about 50 nautical miles east of Denver, when this fireball appeared. It originated due east of us about 15° to 20° above the horizon, just to the left of Procyon, and streaked toward the horizon in a direction from 1:00 to 7:00.

It originated as a bright green-yellow streamer and lasted several seconds burning out just above the horizon in a bright yellow-orange flash. It was bright enough to light up the scattered middle altitude clouds in the area.

This was the brightest meteor I have ever seen and I would be interested to know if you receive any other sightings that would be useful in determining its track.

I shall watch your In Focus section for any information.

George D. McCullough
Gig Harbor, WA

Space Apathy

Sir / I feel compelled to respond to Mr. David Fabrizio's letter of January 1980 in which he bemoans the public's apathy toward manned space flight in the post-Apollo era. Mr. Fabrizio tells us "...that the average American was not intelligent enough to understand just how immense Apollo was or how great its potential could have been." It is with trepidation that I take up the challenge offered by one so far above the average.

Why is the public apathetic towards manned space flight? The question can be answered to a large measure by examining the history of the manned space flight program itself.

The idea of going to the Moon was first seriously advanced during the early days of the Kennedy Administration, at the height of the Cold War, when American interests and pride appeared to be on the ropes. A U.S. backed regime in Laos was near defeat, Fidel Castro was in Cuba, Yuri Gagarin was in orbit, and the Bay of Pigs invasion was a humiliating failure.

The Moon was proposed as a rallying point for flagging U.S. prestige and influence. A flight to the Moon was something that nobody had done yet. It was something we had a chance of doing first. It would help regain international prestige. Never mind that it in no way dealt with the earthly problems at hand, in fact, that it distracted attention from those problems.

At first, the distraction was well received. But as we approached the Moon and finally attained it, in the late sixties and early seventies, we were also witnesses to other spectacles. The devastation of Vietnam, "side shows" in Cambodia and Laos, race riots, civil and violent disobedience, the disgrace and downfall of both a Vice-President and President, and the assassinations of several beloved leaders.

A moon flight was originally conceived as a political extravaganza, a rallying point for the people. With a backdrop of social chaos, the moon flights were recognized for what they were: political extravagance of the very worst kind — flamboyant, technical pomp. Apollo was a show, a very good one, but just a show.

Yes, there were scientific experiments, but Viking, Pioneer, and Voyager have shown that unmanned craft can do almost as much and for half the price.

Apollo was followed by Skylab, in my opinion the one manned spacecraft yet flown that was worth the price. But hard science had to make way for the wholly pointless Soviet-U.S. Joint Mission, more flag waving and public malaise.

Now with the Shuttle, manned space flight is ready to go to work but the public has had enough. After a nearly uninterrupted twenty-year history of senseless outer space hubbub, I can hardly blame them. NASA is going to have to reconvince the public that men and women should fly in space, this time because it is useful, not just because it is fun.

One last point, to close an already too long letter, I do not believe, as Mr. Fabrizio obviously does, that average Americans regard the universe with ignorance and lack of interest. The remarkable growth of the telescope industry, and the very magazine this letter appears in, attests to a growing interest in astronomy. I hope that ASTRONOMY continues to aim at least a few of its articles at entry level enthusiasts. And I hope that average Americans, interested but still uninvolved in astronomy, will not be repelled by the bitter contempt that Mr. Fabrizio holds for them.

Scott Conklin
Cortland, NY

Skywatching

Sir / Last night as I was driving to work, I looked toward the sky to check the progress Jupiter and Mars had made across the heavens. It had been cloudy and rainy for the past eight to ten days.

What I found was the Moon approaching full phase, sitting just below and right between both planets.

What a pleasant surprise! Since I work outside, I was able to watch this celestial ballet. How peaceful it seemed as they slowly sank toward the horizon, silently slipping through the void of space.

Oh, to be standing on the red, rock-strewn plains of Mars, looking inward at a bright blue and white marble making its way along its own orbital path.

Well, perhaps our children will witness just that. We can hope.

Michael R. Foley
Troy, NY

Ooops!

In the lead article for April, an editorial oversight turned the Soviet Lunokhod probe into a sample-return mission. 'Twasn't so: Lunokhod was a remotely-piloted rover vehicle; the sample returns were made by Lunas 16 and 20.

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behind the scenes

photo submissions

The morning avalanche of mail at our editorial offices usually contains about a dozen photo submissions. We examine these carefully looking for pictures we can use in ASTRONOMY features, departments, and, of course, for the winner of the monthly "Best AstroPhoto Award." Here are a few tips that will help both you and the staff at ASTRONOMY.

- We will either accept your picture for possible use in ASTRONOMY, or if we can't use it, we'll return it promptly.
- We'd like to publish every picture we accept right away, but we may not have an immediate place for it. We hold many photos on file for future use. We often publish photos that have waited in our files for long periods of time.
- Each month we'll pick one outstanding astrophotograph for our "Best AstroPhoto Award."
- Submit photos as color slides, color prints, or black and white prints. We prefer prints 5 x 7 inches or larger. Do not send negatives: if we need them, we'll write and ask you for them.
- Label *each* and *every* photo submitted. For slides mounted in cardboard, small glue-backed address labels are best. Labels don't stick reliably to plastic slide mounts, so write your name and address with plastic ink (available in art stores) on the mount.
- Do not write or type on prints. This causes bumps on the picture side. Use adhesive labels on the back of color or black and white prints and don't put the label in the center; put it near the edge.
- Don't send us originals you don't want us to hold. Have duplicates of them made for yourself before sending slides to us.
- We'll return your submission even if you don't enclose a self-addressed stamped envelope, but we appreciate them.
- Please allow enough time. It takes four to six weeks for letters both ways, our review of your pictures, and our response.
- On each photograph or slide include all pertinent technical data: film, exposure time, f/#, type of telescope or camera and lens. Give the manufacturer and model name of your telescope — and if it's home-made, let us know that, too.
- We pay a $10 honorarium for each photo (either color or black and white) that we publish. (We've raised the black & white rates.) Payment is on publication, and is for the use of the photo only. All rights remain *your* property unless we make other mutually agreeable arrangements with you.

Sincerely,

Richard Berry

Richard Berry

P.S. We're making our 1979 Index to ASTRONOMY available free for the asking. Just send us a self-addressed business size envelope with 15 cents postage. Mark your letter "Index" on the outside. Thanks.

ASTRONOMY REVIEWS

Protostars and Planets
Tom Gehrels, editor
hardcover, 756 pages, $17.50
University of Arizona Press (1978)

Those with a merely casual understanding of astronomy may find *Protostars and Planets* heavy going; it is frankly aimed at the graduate student level and higher. But don't let the weight (one kilogram), length (756 pages), esoteric-sounding titles ("On the Angular Momentum Transfer and the Accumulation of Solid Bodies in the Solar Nebula"), and mathematics throw you off. The dedicated amateur astronomer and educated layperson will find this book fascinating. It is a fine sourcebook, with the latest information and theories on the formation of stars and planets.

Protostars and Planets consists of an introduction by Tom Gehrels, three overview chapters, and 35 more detailed papers on one of the most exciting areas of astronomy — what Gehrels calls the emerging discipline of "Originary Sciences" or "Astrogeny."

Gehrels has done a fine job of tying together many different papers into a cohesive work. Despite what we have learned in recent years about the origins of stars and planets, the field of astrogeny is still in its infancy. Astronomers agree on some things, for example that stars form from the collapse of interstellar clouds of gas and dust, but there's still much disagreement on the mechanisms causing that collapse. Is it spiral density waves in the galaxy? Supernova shock waves? Both? What processes reduce circumstellar dust and gas clouds into planets: gravitational collapse? condensation? some form of accretion? all of the above? Indeed, as William K. Hartmann points out in his review chapter on planetary formation: "We still have no proof of the existence of planetary masses near other stars...."

The 51 authors included in this book do a good job of covering the many questions arising in the field of astrogeny. They present their information and theories in a well-written and clearly understandable manner.

These 35 review papers are gathered into five major areas: grains and chemistry, clouds and fragmentation, associations and isotopes, protoplanets and planetesimals, and cores and stellar winds. Some of the specific topics covered include current problems in interstellar chemistry (William Watson); how cosmic grains may form (Bertram Donn); how and why molecular clouds break into smaller fragments (Joseph Silk); statistics about binary star systems (Helmut Abt); the connection between supernovae and star formation (Charles Lada, William Herbst, George Assousa, David Schramm, and Hubert Reeves); the formation of terrestrial planets (George W. Wetherill); and the current status of models for T Tauri stars (Roger Ulrich).

The role of supernovae in the formation of stars is explored in several chapters. There's strong evidence of stellar formation directly connected with a supernova, as seen in the Canis Major R1 ring. The recent discovery of an excess amount of the magnesium-26 isotope in the Allende meteorite suggests a supernova exploded near our solar system early in its evolution. Was it after the Sun formed from its interstellar cloud womb? Or did the supernova shock wave actually trigger the cloud collapse that formed our solar system? *Protostars and Planets* examines all sides of the question.

What connection, if any, is there between multiple-star systems and stars with planets? In his chapter on binary stars, Abt notes that nearly half of all stars are multiple and perhaps three-quarters of all stars have companions of some kind. Binary stars with short orbital periods seem to form in one way, long period binaries in another. But there's still no real evidence that binaries are likely to have planets, or that there's even a continuous progression from binary stars to stars with planetary companions.

Several chapters near the end of the book explore the fascinating problem of the T Tauri stars. These pre-main-sequence objects resemble our young Sun and its solar nebula. Catherine Imhoff suggests that planetary formation occurs before the T Tauri phase and its associated large mass loss, fast rotation, and infrared radiation. Many models exist to explain these phenomena, but as Robert Ulrich notes: "No models are yet completely satisfactory."

That is the final message of *Protostars and Planets.* No models are yet completely satisfactory for explaining the creation of stars and planets. That's why this field is so exciting — and why this book is so interesting to read. It belongs in the library of anyone who wants to stay on top of the standing shock wave of astrogeny. *Joel Davis.*

Graze Observer's Handbook
Harold R. Povenmire
180 pages, hardcover, $8.50
JSB Enterprises, second ed. (1979)
[order from: 763 Pinetree Drive,
Indian Harbour, FL 32937]

The novice telescope owner is sometimes perplexed by the question of what to do with his or her observing time after mastering the fundamental skills necessary for good observing. Despite oft-repeated rumors, there *do* exist a few projects that can contribute valuable knowledge to the scientific world and which can be done with amateur telescopes. These include eclipse and solar observations, variable star observing, blink-comparator work, comet hunting, meteor observations, and, according to Harold Povenmire, grazing occultations.

Mr. Povenmire points out in the foreward of his book that the term "'grazing occultation' still does not appear in astronomy texts fifteen years after this field was started" and that it is his intention to "help open the door to the amateur and professional astronomer who wish to do some valuable work and make a genuine contribution to science."

Exactly what this "valuable work" or "genuine contribution" really is may leave the uninitiated reader a bit confused because neither is adequately explained in the book. In fact, it is entirely possible for the would-be graze observer to read *Graze Observer's Handbook* cover to cover without ever understanding what a grazing occultation really is!

(For the record, then, a grazing occultation is when the Moon just skims past a planet or star in such a way that the object appears to duck in and out behind lunar peaks and valleys.)

This book suffers from numerous maladies, the most serious of which is a failure to define adequately procedures and terminology used by a graze observer. The most glaring goof of this type is the author's use of the phrase "reduction of data." After observing and recording a grazing occultation, you must analyze the data (your observations) in order to learn what was discovered. This is the most important part of the entire project, and here the book loses its way hopelessly in ambiguous statements and half explanations.

The very word "handbook" should mean that the publication contains everything you need to know about the subject, explained clearly and concisely. Mr. Povenmire fails to do this. You are never told what is actually involved in the reduction of graze data, step-by-step or otherwise. Here, as in other explanations in the book, the author is hung-up on observing technique rather than explaining the full process from observation to analysis. (Other less important, but still annoying, errors are numerous typos and awkwardly worded sentences.)

On the more positive side, the book *does* contain fairly well-arranged chapters. However limited their information, the first five chapters introduce you to lunar features and motion, and grazing occultations. But again, it is here that the reader may be most confused, as improper explanations of important material abound. What you need to know is: 1) what total and grazing occultations are and what they look like; 2) what the procedures are for obtaining good data; and 3) how to interpret them. The information contained in this section of the book is totally inadequate in answering these questions.

The remaining chapters relate to choosing equipment: telescopes, tape recorders, star catalogs, etc. Also summarized are the necessary qualifications for a project team leader, where to get topographic maps for plotting limit lines and choosing observing sites, how to organize a graze expedition, how to handle common difficulties which may arise, weather problems, and others. These chapters are the most informative, based as they are on the author's experience in organizing graze expeditions.

Graze Observer's Handbook is now in its second edition, the first having been published in 1975. Refinements in the second edition are few; two new chapters entitled "Potpourri" and "Sixty Second Astronomy" make up half of the additional 46 pages added. There are no illustrations, except for several poorly defined and explained charts from past grazes. This is too bad because diagrams and photographs could aid greatly in helping a reader grasp the concepts.

Graze Observer's Handbook is the only book currently available on the subject. Unfortunately, it can only be recommended as an initial source book and the would-be observer will do well to seek out like-minded observers (try the local astronomy club) so that the burden of learning the many "tricks of the trade" is eased a lot. *Dan Koehler.*

Albert Einstein's Theory of General Relativity
Gerald Tauber, editor
352 pages, hardcover, $14.95
Crown Publishers (1979)

1979 marked the centennial of Einstein's birth, and this book celebrates the event by providing a thorough-going overview of Einstein's work. There are 74 articles by Einstein himself — about a third of the articles — the remainder being written by other people, many of whom worked with him. The level of exposition is variable, ranging from equations to anecdotes, though the former are somewhat more common. At the end is a glossary-index.

A Window in the Sky
A. T. Lawton
223 pages, hardcover, $17.50
Pergamon Press (1979)

Subtitled "astronomy from beyond the Earth's atmosphere," this book reviews the importance and means for conducting astronomical research with space vehicles. Reviewing past successes and hoped-for future missions (via Shuttle and other carriers), Lawton ends up taking the reader on a survey of contemporary astronomical problems.

X-Ray Astronomy
W. A. Baity & L. E. Peterson, eds.
558 pages, hardcover, $95
Pergamon Press (1979)

In May and June 1978 most of the world's X-ray astronomers met in Innsbruck, Austria to discuss new results, observations, and theories. This book is the record of the meeting and will provide the technically-minded reader with an excellent overview. (The price is outrageous for a book that has been "set" by typewriter — and not even on one machine at that.)

Source Book in Astronomy and Astrophysics, 1900-1975
Kenneth R. Lang and Owen Gingerich, eds.
922 pages, hardcover, $50
Harvard University Press (1979)

This is a compilation of the 132 most important papers published in the field between the dates in the title. The papers vary in level: Hale's advocating constuction of the 200" telescope is aimed at the general reader; Bethe's on stellar energy production bristles with equations. Most of the contents are for the professional astronomer.

Extraterrestrial Civilizations
Isaac Asimov
282 pages, hardcover, $10.00
Crown Publishers (1979)

The Good Doctor asks "Are we alone?" — a question that ranks in many minds as The Big One. Having posed it, Asimov then proceeds to define, as best as possible, just what life is and what the prospects are for running across it elsewhere. Asimov is in his usual readable form throughout, and the subject matter will appeal to many people.

Techniques and Methods of Radio-Astronomic Reception
N.G. Basov, ed.
150 pages, paperback, $37.50
Consultants Bureau (1979)

This is a translation of a Russian multi-author work published in 1977 dealing with development of radio and radar telescope systems.

equipment atlas

how to build a dobsonian telescope, part 1

by Bob Kestner and Richard Berry

Would you like to build a bigger and more powerful telescope than you ever thought you could own — for an amazingly low price? Well it's possible, with hand tools and readily obtainable materials, to build a 10″ f/5 or f/6 Newtonian reflector for $250 to $350 — the total depending mainly on how many accessory parts you buy rather than make yourself. This is John Dobson's amazingly simple telescope design (see the April 1980 Forum interview with John Dobson).

Dobsonian telescopes are for people who wish to explore the heavens with a telescopic "eye" much larger than their own. They are inexpensive, virtually problem-free, and by far the most transportable big telescope design available. Dobsonian telescopes are ideal for looking, and seeing, with a telescope that helps you rather than hinders you.

What's this design got going for it? First, it uses common materials: plywood, plastics, cardboard. Machine tools are not necessary to build one. Second, it relies on clever design, based on sound principles of physics and engineering, rather than mass and precision for its performance. Third, it provides a fast, convenient, large-aperture instrument that meets the needs of a growing number of deep-sky observers.

How does it work? Simple. Let's take a look at our 10″ telescope starting from the ground up. The whole telescope sits on three blocks of wood called the *feet*. The feet are attached to the underside of the *ground board*, a thick piece of plywood about 16″ square. Attached to the top of the ground board are three teflon plastic pads about 1½″ square and ⅛″ thick. Riding on the pads is a sheet of formica.

Teflon is the super no-stick plastic now famous for its use in the bottom of frying pans, and formica is the stuff of kitchen countertops. Formica slides very, very smoothly on teflon. The *bottom board* may simply sit on the formica sheet, or it may be glued to it. Passing through the whole arrangement at the middle is the *center bolt*. The formica sheet turning on teflon pads is an extremely smooth bearing, yet it's almost unbelievably simple.

The bottom board is the bottom of a box, called the *rocker*, that supports the telescope. Two *side boards* about 16″ high are attached to the bottom board, facing each other. Another piece called the *front board*, attached to both side boards and the bottom board, keeps the side boards rigid and upright. Two *cradle boards*, with half-circles or V-notches cut out of them, are attached to the inside of the side boards, and these are what the telescope actually swings between. (Sometimes the cradle boards are eliminated, and the notches are cut directly into the tops of the side boards.)

Photographs by Gerald R. Sibert

Riding on the cradle boards are two disks 4″ to 8″ in diameter, one attached to each side of the box holding the telescope's tube (sometimes directly to the telescope tube itself), called the *side bearings*. These bearings, which can be made of plastic, metal, or even wood, are held in place by the weight of the telescope. (Sometimes a telescope is provided with four side bearings so that the tube can be rotated to bring the eyepiece into the most comfortable position.)

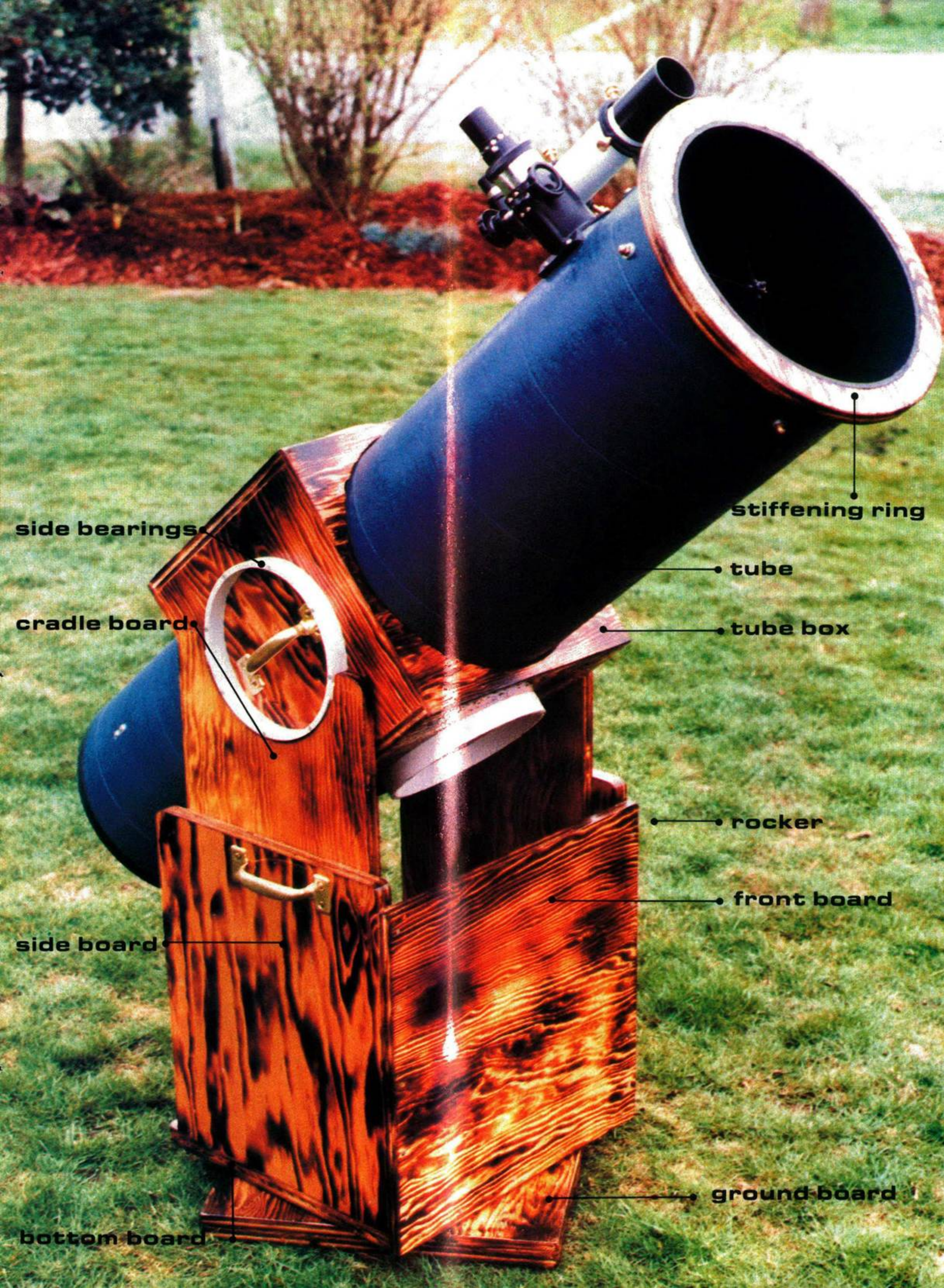
Finally for our 10-incher, the tube, 12″ in diameter and 5′ long made from cardboard concrete-form material called Sonotube, sticks out both ends of the box. Most Dobsonian telescopes use the simple, inexpensive Newtonian optical system. If you make the mirror cell, the diagonal and spider support, and eyepiece holder yourself (and it's quite simple), you can save quite a bit of money. Or, of course, you can buy the components and the tube off the shelf.

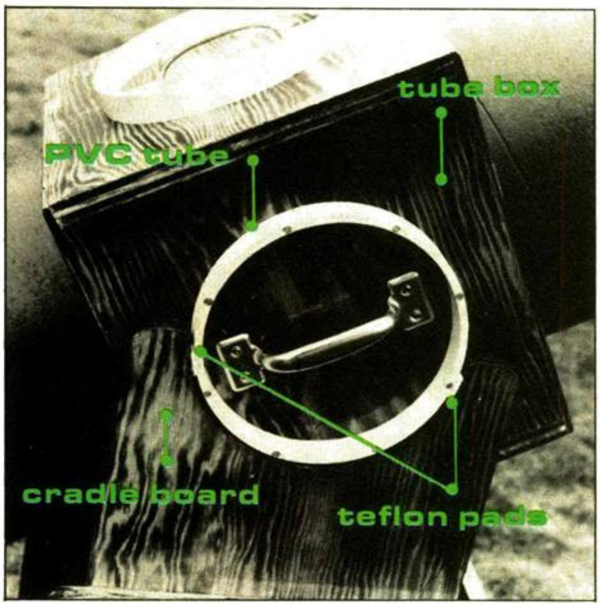
Materials

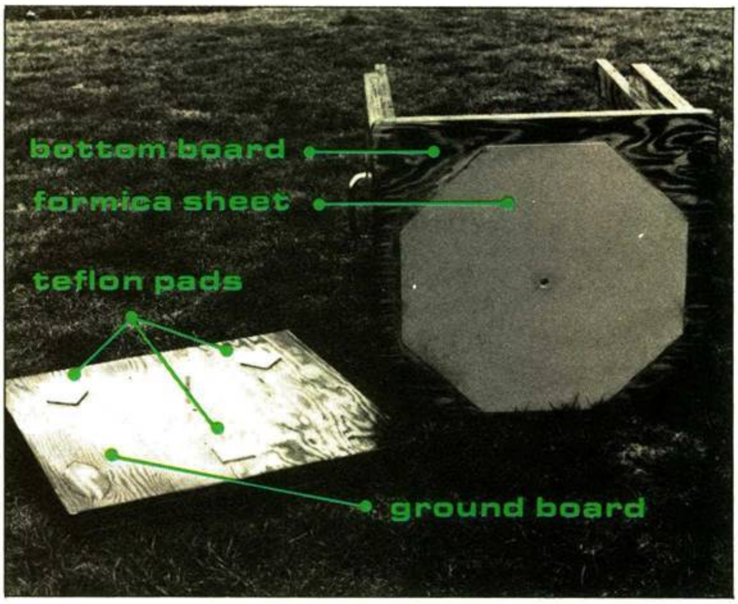
Although Dobsonian telescopes are built entirely from commonly available hardware and industrial materials, you may not know where to find them in your area. Remember that if you can't find exactly the materials we specify, you can make some substitutions.

Plywood, of course, can be obtained from lumber stores and "Home Improvement Centers." You want a standard 4′ x 8′ sheet ¾″ thick. The grade of wood or surface quality is not critical, but it's a good idea to buy "Exterior" material because its glue is waterproof. Check the sheet for splits, cracks, or open laminations. Do not substitute particle board, chip board, hard board, or composition board for plywood — they don't have the stiffness of plywood.

The home improvement center and lumberyard will also carry the formica sheet you'll need, sold as kitchen countertop material. You can buy or beg pieces of countertop called "sink cut-outs," which are formica, conveniently bonded to particle board. You can also buy formica by


stiffening ring
side bearings
tube
cradle board
tube box
rocker
front board
side board
ground board
bottom board





bill of materials

(typical prices)

10″ f/5.6 mirror	**$110**
2.5″ diagonal	**$20**
Sonotube[1]	**$10**
4x8 foot ¾″ plywood	**$20**
misc. hardware	**$20**
paint	**$7**
teflon[2]	**$6**
sink cut-out	**$2**
side bearings[3]	**$10**
6x30 finder	**$30**
mirror cell[4]	**$20**
spider[4]	**$25**
eyepiece holder	**$40**
Subtotal	**$320**
2 eyepieces	**$60**
Grand Total	**$380**

1. **$1.45 a foot plus $1.00 per cut; may vary.**
2. **$12 per pound; ⅛″ weighs 1.5 lbs/sqft.**
3. **Or get two 5″ closet flanges at $3 each.**
4. **No extra cash expenditure if homemade.**

itself. The best kind has a very slightly textured surface, but the smooth kind works well too.

Sonotube is a waxed cardboard concrete form tube with ¼″ thick walls. Building contractors use it for casting concrete columns: they set the tube in place, fill it with concrete, and after the concrete has set, cut the tube off. It comes in 2″ inside diameter increments. You want about six feet of 12″ Sonotube. To find a supplier, check the Yellow Pages for places that sell materials to building contractors. Sonotube looks pretty grubby, the amount of wax coating varies from batch to batch, and it's sometimes nicked and scuffed. We'll tell you how to fix it up in part 2.

The biggest problem in finding teflon plastic for the bearing is that you're buying so little that firms that sell it may not want to deal with you. If possible, get several people to buy together. Look for suppliers under "Plastics—Rods, Tubes, Sheets, Etc. — Supply Centers" in the Yellow Pages. You'll want a piece of ⅛″ or 3/16″ sheet teflon about 6″ square. That's about three times the amount you actually need, but buy the extra. When your friends decide to build their own Dobsonians, give them your excess. You can substitute nylon floor glides or the soft plastic lids of Kodak film cans for teflon, but they're not as good.

The side bearings should be as large as possible — around 4″ to 8″ for your 10″ telescope. Best are 1″ thick slices of ½″-wall PVC tube (get it from the same plastics dealer who sold you the teflon), but molded PVC plastic closet flanges work very well also. You can get them in the plumbing section of well-equipped hardware stores, or from plumbing supplies dealers. (Genova is one of the most common brand names.) Get the 5″ size if you can, but if you can't find it, the more common 4″ size works pretty well.

Telescope builders have traditionally ground and polished the primary mirror for their telescopes. This was an economic necessity for most people. For example, just after World War II, a 6″ mirror cost about $60 — a lot of money in those days. Today, an equally good 6″ mirror sells for $40. Prices for 10″ f/5 or f/6 precision paraboloidal mirrors today run from $105 to somewhere around $175 with insignificant differences in quality. If you want to make your own mirror for the fun of it or to learn how, then get a mirror kit and do it — it's lots of fun.

The accessory parts for your telescope — the mirror cell, the spider and diagonal mirror holder, the eyepiece holder, the finder, as well as the telescope mirror and diagonal — can be purchased from mail order suppliers advertising in ASTRONOMY, or can be made at home, depending on your skills and home workshop.

This is the first of a three part series on building a Dobsonian telescope. Part 1 deals with the materials and where to find them, part 2 tells you how to assemble the mounting for the telescope, and part 3 explains how to build accessories and install and align the optics.

Bob Kestner is a long-time designer of Dobsonian telescopes, and is employed as a professional optician. In addition to helping many others in the San Francisco area build Dobsonians, he has completed an 18″ of his own, and has written about Dobsonians in TELESCOPE MAKING #4 and #5.

Posters From ASTRONOMY

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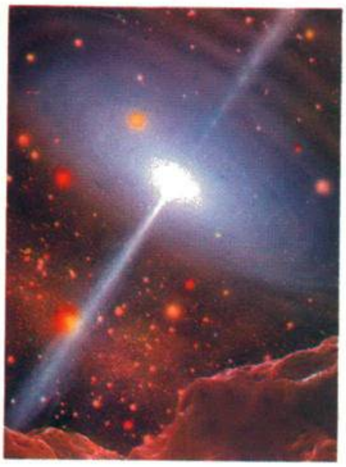

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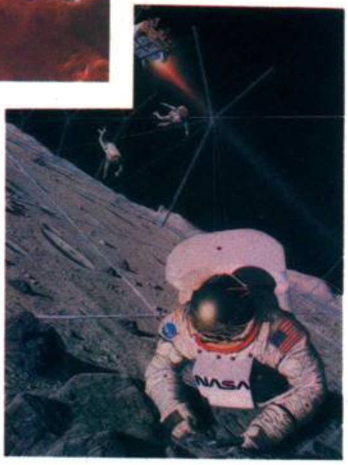

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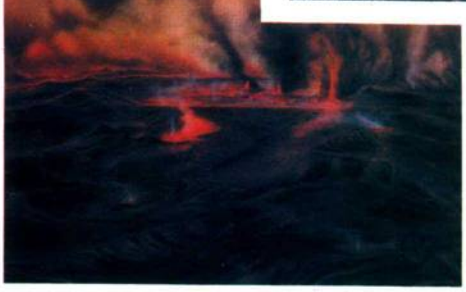
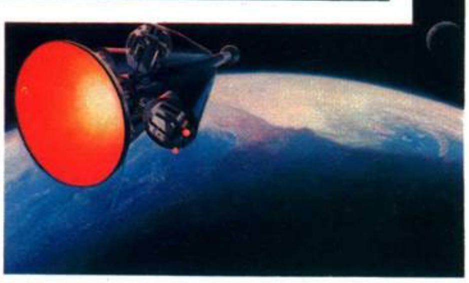


1. Radio Black Hole
   by Adolf Schaller
2. Asteroid Miners
   by David Egge
3. Tharsis Erupting
   by Mark Paternostro
4. Zeta Reticuli
   by John Clark
5. Black Hole
   by Mark Paternostro
6. The Sun From Pluto
   by James Hervat

4



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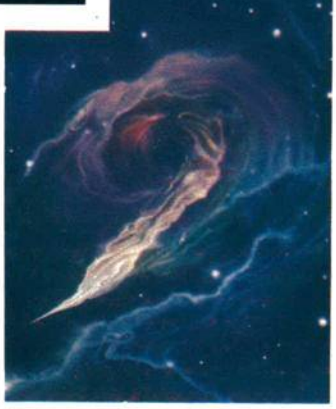

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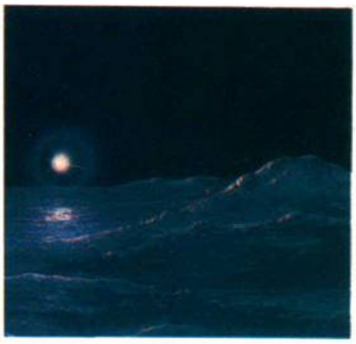

Please order posters by name and artist on the form between pages 60-61.

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NASA Budget Cuts Hit Space Science

Less than two months after releasing what appeared to be a good budget proposal for fiscal 1981, NASA has been forced to cut back, reducing or eliminating many important programs originally included in the budget.

Most heavily cut is space science, with resultant delays in the International Solar Polar Mission and future Spacelab flights. Space Shuttle, NASA's major project, was unscathed. Cuts were also made in space applications and technology, but not to the same extent as space science. (See AstroNews, April 1980.)

Dr. Alan Lovelace, NASA's deputy administrator, told the House space subcommittee that the cuts are painful but not crippling, and would allow much of the work to be picked up in later budgets. NASA administrator Robert Frosch later said that space science bore the brunt of the cuts because that was where the money was most easily found; NASA had to reduce its outlays, the signing of checks, and space science had fewer ongoing obligations than other areas.

Total cutback will be $219 million in the budget plan, reducing it from $5.737 billion to $5.518 billion, and $224 million in outlays.

Highlights of the cutbacks are:

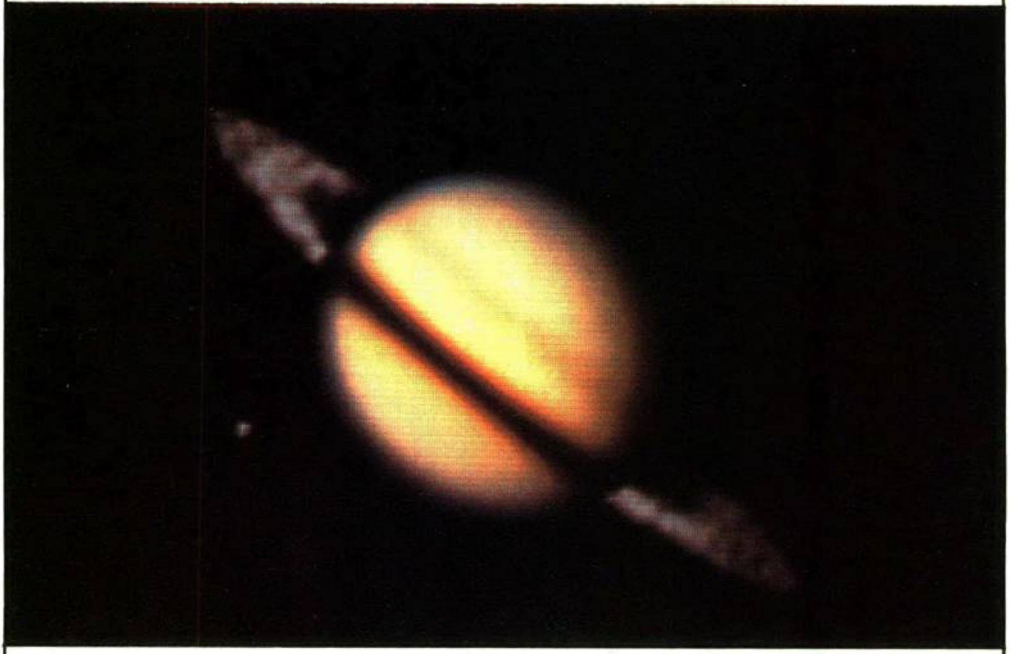
- Space Science: Almost half of the cuts are here, a total of $107 million. The International Solar Polar Mission, a U.S.-European project, will be delayed two years by taking $43 million out and deferring construction of the U.S. spacecraft. Another $43 million cut will be made in Spacelab payload development and mission management. In planetary exploration, $4.3 million will be cut by recording but not analyzing data from the solar-orbiting Pioneers 6-9 and the deep-space Pioneer 11. In life sciences, $6.5 million was taken from flight experiments and another $4.1 million from research and analysis by deferring advanced life support system work.

Good points in this, though, are that the Space Telescope, the Gamma Ray Observatory, and the Galileo orbiter-and-probe to Jupiter were not touched, leaving them on schedule.

A bad point not readily apparent is that all Spacelab missions after the first three now approved will be delayed, as will development of the 40 physics and astronomy experiments announced last August and the 78 life science experiments announced in December. All work in relativity will be suspended for at least a year.

- Space Applications: Resource observations gained $8 million, which conceals cancellation of the operational land observing program and transfer of one advanced sensor to Landsat D. Environmental observations lost $28 million, much of it by delaying the Earth radiation budget satellite. Space communications was reduced by $1 million, killing the advanced communications satellite project, and technology transfer and utilization lost $6 million. Materials processing in space and applications systems were untouched.
- Space Technology: This was cut by $5 million, reducing work in advanced technology for space.
- Space Transportation: Although Space Shuttle itself was uncut, $42 million was dropped from space flight operations, $28 million of it from future Shuttle operations. Proportionally, that may be less significant than the $2 million sliced from advanced programs which had only $10.8 million to start. Many factors went into the decision not to cut Shuttle, including defense missions and the fact that it has been in development for almost a full decade. Federal budget makers are now taking the attitude that Shuttle will not be stopped, and so are trying to get it off the ground as soon as possible. And while many planetary supporters have argued that Shuttle should not go unscathed while planetary flights are restrained, NASA has countered that virtually all space science missions — including Galileo and Solar Polar — are dependent upon the Shuttle as a launch vehicle.

Voyager 1 Approaches Saturn



On March 20, 1980, Voyager 1 returned the above photograph of Saturn to Earth. Taken at a distance of 194 million miles (312,270,000 kilometers), the photograph has been computer-enhanced to bring out detail. A higher sensitivity was employed to picture the dimmer rings, which therefore appear dark where they cross the planet's disk. The moon Rhea can be seen at lower left. Voyager 1 will make its closest approach to Saturn on November 12, 1980, to be followed by the flyby of Voyager 2 in August of 1981. The Voyager missions will return photographs of the saturnian system of much higher quality and clarity than the Pioneer Saturn images obtained last year. NASA/JPL photograph.

Solar Flare Satellite

NASA has placed in Earth orbit the first spacecraft designed specifically for the study of solar flares. The mission represents a major step toward a better understanding of the violent nature of the Sun and its effects on Earth.

The Solar Maximum Mission spacecraft was launched from Cape Canaveral, Florida, on February 14 into an orbit of 574 kilometers (355 miles) altitude. The satellite, carrying seven scientific instruments, is designed to provide scientists with observations of solar flares — violent eruptions on the Sun's surface — over a wide band of wavelengths in the ultraviolet, X-ray, and gamma ray regions of the spectrum.

Through coordinated observations at many different wavelengths, scientists expect to obtain many clues about the complex nature of solar flares and how they might be predicted.

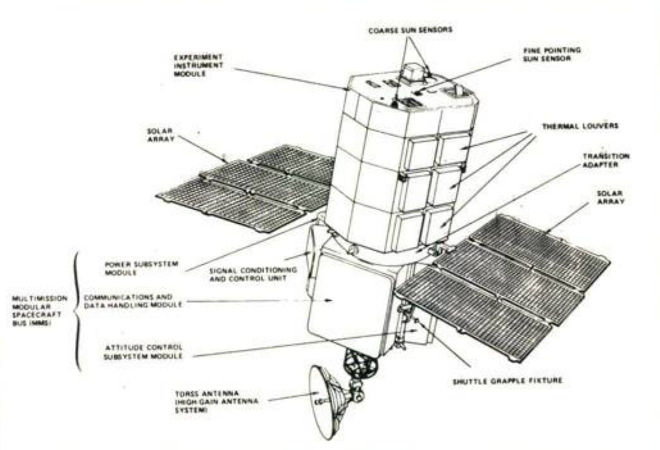
The mission is designed to coincide with the solar maximum period, the peak of an 11-year sunspot cycle when particularly explosive activity disrupts the Sun's surface. The satellite is the pivot of a coordinated program of spacecraft, sounding rocket, and ground-based observations extending at least through February 1981 (see "Solar Maximum Prompts Intense Study of Sun," AstroNews, ASTRONOMY, January 1980).

Although the NASA spacecraft will concentrate on solar flare activity, one of the instruments is also expected to measure the Sun's total radiation output to within one-tenth of one percent over a period of one year. According to computer model predictions of the response of Earth's atmosphere to solar radiation, such a precise measurement should be sufficient to establish definitely whether changes in total solar heat output are sufficient to affect climate and weather (see "A Fading Sun?" AstroNews, ASTRONOMY, January 1980).

Improved knowledge about flares and pre-flare conditions could help scientists predict the occurrence of these complex phenomena. On the basis of available evidence, however, scientists have inferred this much:

The magnetic field extending out through the surface of the Sun somehow gathers itself into an enormously compressed bundle to form a magnetic knot. This becomes visible as a sunspot, a region whose dimensions often are greater than the entire Earth, and sometimes as a looping cloud of dense gas, hundreds of thousands of miles long, known as a solar prominence. (See "Sunspots," ASTRONOMY, May 1980.)

Solar flares erupt close to but not exactly over the sunspots. It is not known precisely how or why the enormous energy release takes place. Theorists believe that the energy comes from the electric currents associated with the strong magnetic fields on the Sun.


COARSE SUN SENSORS
EXPERIMENT INSTRUMENT MODULE
FINE POINTING SUN SENSOR
SOLAR ARRAY
THERMAL LOUVERS
TRANSITION ADAPTER
SOLAR ARRAY
POWER SUBSYSTEM MODULE
SIGNAL CONDITIONING AND CONTROL UNIT
MULTIMISSION MODULAR SPACECRAFT BUS (MMS)
COMMUNICATIONS AND DATA HANDLING MODULE
ATTITUDE CONTROL SUBSYSTEM MODULE
SHUTTLE GRAPPLE FIXTURE
TDRSS ANTENNA (HIGH GAIN ANTENNA SYSTEM)

The Solar Maximum Mission spacecraft carries seven scientific instruments designed to study solar flares over a wide range of wavelengths. The satellite, weighing over 5000 pounds and about 13 feet long, is capable of pointing to any region on the solar disk to within 5 seconds of arc. NASA diagram.

Flares occur about 8000 kilometers (5000 miles) above the Sun's surface, a region where the temperature is about two million degrees C (3.5 million degrees F). The largest flares release energy equivalent to 10 trillion one-megaton hydrogen bombs. The release of energy is sudden.

Earth gets only a relatively small portion of the released energy. But even this small amount has effects which can be seen and heard on our planet. When the flares of solar gases and radiation reach Earth's magnetic field and atmosphere, they can cause severe disruptions in radio and television communications, surges in power transmission lines, auroral displays, and possible reductions in the lifetimes of some orbiting spacecraft. Some scientists suspect that increased solar activity also influences Earth's weather and climate.

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- Shuttle Flight Control

Quark Stars?

In the heart of the Crab Nebula and the Vela supernova remnant are two pulsars, all that's left of the giant stars that exploded as supernovas. The Crab and Veil pulsars are considered to be neutron stars, superdense stellar objects in which the matter has been crushed by gravity past the degenerate state into a mostly-neutron superfluid. The neutron star state is the last stop before a final, unstoppable collapse into a black hole.

Or is it?

Back in 1970, astrophysicist N. Itoh suggested that something called a "quark star" could also exist. Quarks are the basic building blocks of matter. So-called elementary particles like protons, neutrons, and pions are themselves composed of either two or three quarks which have differing properties of "color" and "flavor." The nature of the atomic particle depends on the properties of its constituent quarks. According to Itoh, if the neutrons and protons inside a neutron star were sufficiently compressed, the quarks that make them up would break free and interchange. The result would be a phase transition in the matter from neutron superfluid to a "quark fluid."

Is there any way, though, to tell a "normal" neutron star from a quark star? K. Brecher of Boston University and A. Burrows of the University of Michigan think so. In the February 15, 1980 issue of the *Astrophysical Journal* the two suggest that a quark star, though physically the same size as a neutron star, may stay hotter for a longer period of time. Plotted on a graph, the quark star cooling curve is "quite similar to the neutron (star) curves for about the first 1,000 years. At later times, quark stars stay hot longer than neutron models," they report.

Detailed comparisons require more knowledge about quark matter than we currently have. However, Brecher and Burrows have compared the upper temperature limits of the Crab and Vela pulsars with their

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quark/neutron star temperature curves. The uncertainty factors are high, but it's conceivable these two pulsars aren't neutron stars at all, but rather quark stars. It's also possible they're neither, but instead stars with a quark core and a "mantle" of pion particles.

Last of the Pioneers

After 16 years of developing and flying spacecraft to various planets and in orbit around the Sun, the Pioneer Project Office at NASA's Ames Research Center is closing down.

Responsibility for operation of the seven Pioneers still working in interplanetary space is being transferred to the Space Missions branch at Ames. The move is a result of the termination of the Pioneer series of spacecraft.

The Pioneers still operating are: the four Pioneers 6 to 9, which currently form a network of solar "weather stations" around the Sun; and Pioneer 10 and Pioneer Saturn, both headed out of the solar system after the first two flights to Jupiter, and the first flight to Saturn. Pioneer Venus continues to orbit the cloud-shrouded planet photographing cloud circulation, mapping Venus' surface, and taking a range of other data.

The twelve Pioneer missions have all been very highly productive scientifically, and the spacecraft have accomplished several dozen "firsts" in a variety of areas. The Project Office and its staff members have received many awards, including two of international reputation.

"Charlie Hall (Pioneer Project Manager) and all who have participated in the program deserve our congratulations and a hearty well done," said Ames Director C.A. Syverston in a staff memo on the subject. "I want to thank them for being such a great credit to Ames," he added.

NASA Headquarters has just awarded a large number of NASA medals and other recognition to individuals and teams who have made Pioneer go. Hall was given the Distinguished Service Medal, NASA's highest award. He is retiring after 38 years of service with the agency.

The Papago Asteroid

Baboquivari is the highest and most sacred mountain on the Papago reservation, figuring prominently in the tribe's religion and mythology. It is also now the name of a new asteroid discovered by Indiana University astronomers and confirmed and photographed by a University of Arizona astronomer on Kitt Peak.

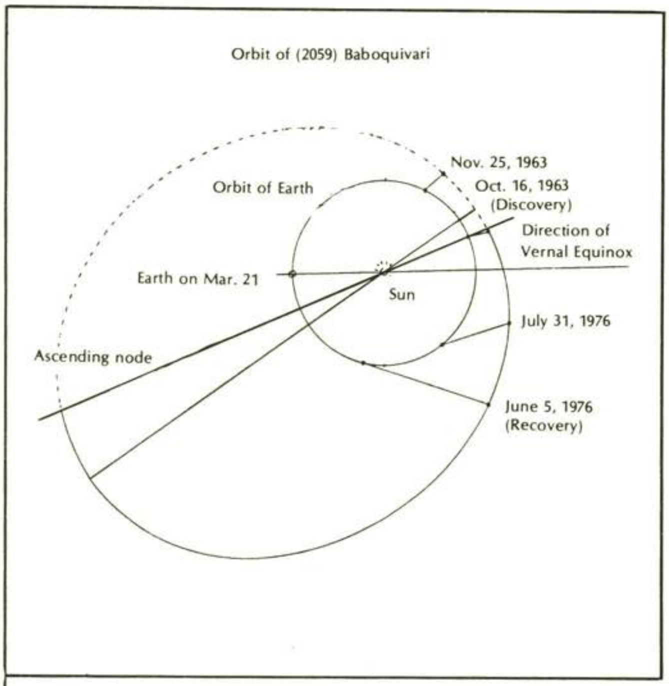
The asteroid's name was recommended by Dr. Frank Edmondson, professor of astronomy at Indiana University, in honor of the Papago people who made available the land on which the Kitt Peak National Observatory (KPNO) was built. The observatory, located 52 miles southwest of Tucson on the Papago reservation, was founded in 1957 as a national center for ground-based optical astronomy. It is operated by the Association of Universities for Research in Astronomy (AURA) under contract with the National Science Foundation.

Following the recent approval of Edmondson's recommendation by the International Astronomical Union's Minor Planet Center, a formal presentation of the asteroid's naming was made to the Papago Tribal Council in Sells, Arizona by Edmondson and representatives from the University of Arizona and KPNO.

The asteroid Baboquivari was first discovered on October 16, 1963 at Indiana University's Goethe Link Observatory. After being in poor position for observations for a number of subsequent years, Baboquivari was photographed by Dr. Elizabeth Roemer of the University of Arizona on June 5, 1976 using the 90-inch reflecting telescope at the University's Steward Observatory on Kitt Peak.

The minor planet's position was in close agreement with the prediction made by B.G. Marsden of the Smithsonian Astrophysical Observatory. Other sightings were obtained by several astronomers throughout the world enabling the minor planet's orbit to be determined precisely and confirming that it was a new discovery. Since the initial sighting was made at Indiana University, astronomers there were given the right to suggest a name.

Favorable opportunities for observation of Baboquivari recur at intervals of 13 years when the asteroid is closest to the Sun in its orbit. Baboquivari may be observable in the late spring and through the summer of 1980, but only through a large telescope. It will reach a magnitude of 18.5 at its brightest. The next favorable opportunity for observation will occur in the fall of 1989.



The thirteen-year orbit of the asteroid (2059) Baboquivari is shown above in relation to that of the Earth.

Gamma Ray Observatory

The Gamma Ray Observatory, a proposed new start in NASA's fiscal 1981 budget, is designed to explore sources of gamma rays in space — the most energetic form of radiation known.

The Earth-orbiting observatory, planned for launch in 1985, will carry instruments which will detect gamma rays in a variety of forms — very high energy gamma rays from pulsars, nuclear gamma rays, and gamma ray bursts.

Scientists expect the information returned to provide a much deeper understanding of the nature of supernovas, pulsars, quasars, and radio galaxies, the character of the universe at an early time, and the possible existence of antimatter in the universe.

Scientists also hope to learn more about the incredibly dense matter which makes up such objects as neutron stars — matter so compressed that a teaspoon of it would weigh millions of tons.

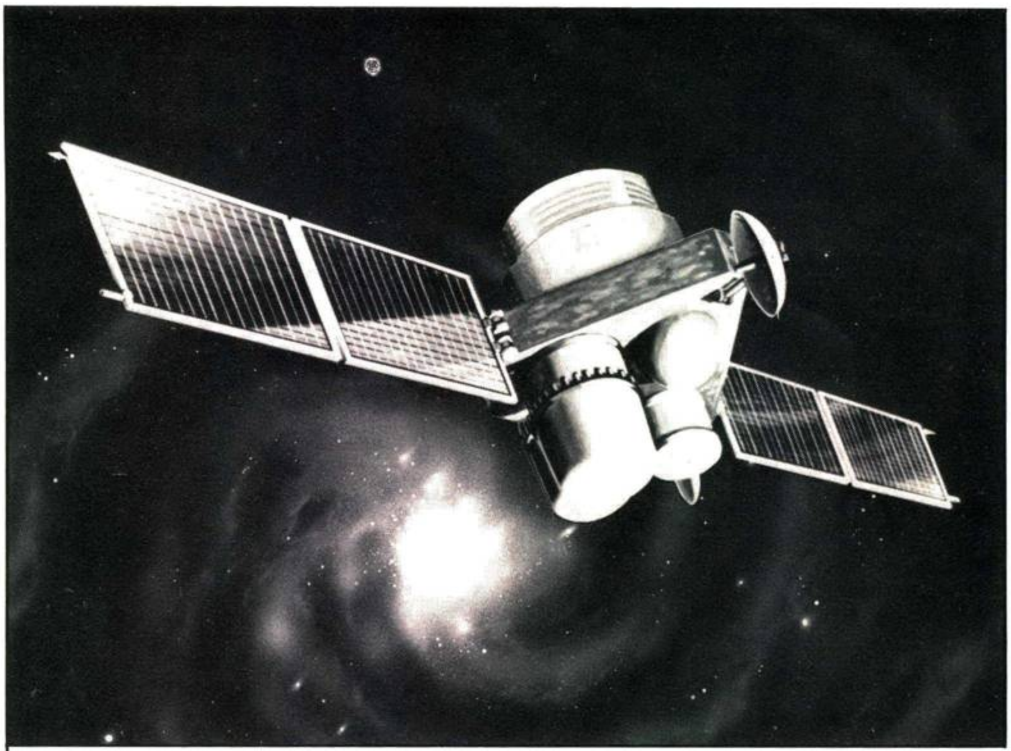
The data may also shed more light on the nature of gamma ray bursts — erratic pulses of gamma rays that appear every month or so and flash across the solar system. Their origin is a mystery.

Like X-rays, gamma rays are a form of electromagnetic radiation (as is ordinary light), but they have extremely high energy and corresponding short wavelengths (less than 10^{-11} centimeters). At maximum strength, a gamma ray photon packs several million times as much energy as a comparable photon of visible light.

Unlike X-rays, however, which are typically emitted by hot gas, gamma rays are believed to come from the core of the phenomenon, produced by special nuclear processes. Gamma ray astronomy allows scientists to investigate these special processes. Until recently all astronomy observations were of atoms, ions and molecules, and their emissions. Gamma rays were recognized after World War II as an important aspect of space research, but work in this field was slow. A long program of balloon research proved rather disappointing, with only hints that gamma ray sources were being detected.

Then a small experiment on an Orbiting Solar Observatory detected the first certain gamma rays. This gave scientists the confidence to launch in 1972 the Small Astronomy Satellite-2 with a small detector for very high energy gamma rays. This spacecraft, along with the European spacecraft COS-B (1975), and the first High Energy Astronomy Observatory (HEAO-1), provided the basic data which will be exploited by the more powerful Gamma Ray Observatory.

The observatory will be managed by NASA's Goddard Space Flight Center, Greenbelt, MD. The satellite will be carried into a planned orbit of 400 to 500 kilometers (250 to 300 miles) by the Space Shuttle. The planned orbital altitude was chosen to be as low as possible consistent with the observatory's two-year design lifetime.



The recently approved Gamma Ray Observatory is the first in a proposed series of advanced missions designed to explore the world of gamma rays—the most energetic form of radiation known to man. Launch of the 19,000-pound spacecraft by the Space Shuttle is scheduled for 1984. The GRO would orbit Earth at a distance of 250 to 300 miles. NASA artwork.

Einstein Mission Extended

NASA's High Energy Astronomy Observatory-2, also known as the Einstein Observatory, originally scheduled to end operations after one year in Earth orbit, will continue to search the skies for information about such objects as quasars, pulsars, exploding galaxies, and black holes. Officials decided that the many significant findings attributed to the spacecraft — which carries the largest X-ray telescope ever built — warranted an extension of its space science mission beyond the projected lifetime of 11 months.

"The performance of the observatory has been excellent throughout the first year of the mission," said Dr. Thomas A. Mutch, NASA Associate Administrator for Space Science. "The operation of the scientific instruments has met or exceeded our expectations."

The instruments continue to operate satisfactorily. A solid state spectrometer, which performed exceptionally well, has depleted its cryogens and ceased operating, as expected.

Among the most significant new findings from the observatory (nicknamed Einstein by scientists who provided the instrumentation on board) are the following:

- The X-ray observation of more than 60 known quasars, ranging from relatively nearby to the most distant objects known, and the discovery of more than a dozen previously unknown. These findings open an important new approach to the study of the nature and evolution of these objects.
- The determination that a substantial fraction of the extragalactic radiation background may be due to scattered individual sources. This finding has important consequences regarding the question of an open or closed universe.
- The surprising absence of hot neutron stars at the center of supernovas (exploding stars), which requires new cooling mechanisms to be postulated for the remaining core of a supernova explosion.
- The discovery that the coronas of certain main sequence stars emit X-rays with greater intensity than had been predicted by current theories. This finding requires a substantial rethinking of energy-transport mechanisms in stars.

"Based on this early indication of significant results, I have authorized an extension of the observatory mission in order to continue this exciting series of investigations," Dr. Mutch said.

A continuing activity with the observatory is NASA's Guest Investigator Program in which scientists use data from the spacecraft for studies not directly related to the planned objectives. Since the launch of the observatory, about 400 guest investigator proposals have been received by NASA. They were submitted by more than 80 groups from the United States and other countries, including Great Britain, France, Germany, Italy, Russia, India and Japan.

The Einstein Observatory is the second in a series of three spacecraft designed to survey the sky for X-ray, gamma ray and cosmic ray sources. The first observatory, launched in 1977, conducted an all-sky survey and mapped about 1,500 X-ray sources, many of which were subsequently correlated with visible objects in the sky. It also measured, for the first time, the temperature of the uniform high energy X-ray background. Many scientists believe these X-rays originated from a universal hot plasma thought to constitute a major fraction of the mass of the universe. The third high energy observatory, launched last September, is conducting an all-sky survey of cosmic and gamma rays, but at higher energies and from a higher orbital inclination than the first observatory. It is unique in its ability to search for not only the known elements, but also theoretically predicted elements heavier than any yet discovered either on Earth or in space. These trans-uranian elements would be an indication of extremely high-energy processes taking place deep in space.

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Scopes for the 90's

At the invitation of Dr. Geoffrey Burbidge, Director of the Kitt Peak National Observatory, almost 250 astronomers, engineers, and optical designers from around the world gathered in Tucson this January to discuss the construction of very large optical and infrared telescopes which would come into operation in the last decade of the century. The first session, "Ongoing Programs Involving New Telescopes," featured presentations on European, Russian, Chinese, and United States current plans for large optical and infrared telescopes. During the week there were sessions on how ground-based and space developments relate to each other, instrumentation and detectors, science to be done with telescopes of the 1990s, general telescope technology, and specific telescope concepts.

Dr. Donald Hall who heads Kitt Peak Observatory's Next Generation Telescope Program explained that the worldwide interest in large new telescopes is being generated by technical developments which have opened the way to radical design approaches which will greatly reduce the cost of large telescopes. Commenting on this, Dr. Hall pointed out that:

"Large telescopes being planned for the 1990s could provide more light collecting area than all telescopes now available to professional astronomers."

The Multiple Mirror Telescope (MMT) — several large mirrors on one mount built at a cost substantially less than the cost of a telescope with a single mirror but comparable in light gathering power — was recently completed by the Smithsonian Institution and the University of Arizona. This telescope is situated on Mount Hopkins, about 50 miles from Tucson. This is one type of new telescope, but many other designs for even larger telescopes were studied and discussed at the Tucson conference.

Shuttle Flight Control

Although it somewhat resembles a futuristic movie prop from the latest space epic, Mission Control Center at NASA's Johnson Space Center in Houston is a place where serious technicians are engaged in a great adventure — the quest for knowledge.

Today, Mission Control is preparing for the initial Earth-orbital flight of America's first manned Space Shuttle. The reusable Shuttle will be rocketed into orbit and glide back to Earth after its mission is completed.

The Space Shuttle, as workhorse of the space program, will carry communications satellites, weather satellites, and scientific experiments into space on a regular basis, return to Earth and a few weeks later, re-enter orbit with another payload.

NASA has worked out a pay-as-you-go plan to allow individuals, companies, universities, foreign governments, and others to rent space in the large cargo area for scientific experiments. Such space aboard the Space Shuttle is totally sold out for the first 42 flights.

Before the actual launch, simulated missions are conducted to check out each detail of the equipment. Establishing an effective interplay between people and machinery is the most difficult of all problems in developing a spacecraft operational system that works. There are approximately 75 controllers working each of the eight-hour shifts in the Mission Control Center to make certain the flight operations work perfectly in all aspects and at all times.

The controllers work in teams — each with a different function. The flight control team is composed of technical representatives from the many technical disciplines.

These staffers monitor the whole variety of spacecraft subsystems, including life support, thermal control, propulsion, navigation, flight operations, communications, and vehicle systems. There are specialists who work on trajectory patterns, those who work with experiments, and those who direct NASA's worldwide tracking network.

Each controller constantly monitors the telemetry from the spacecraft, evaluating the performance of the system which is his or her responsibility, verifying that it is working properly, and observing the crew's use of the system to make certain it is responding correctly.

The simulated tests are as close to the real action as one can get. Pete Frank, Chief of the Flight Control Division at Johnson, said: "...it can get so realistic that there are times when you actually forget you are simulating. You become so involved and so wrapped up in the simulation that sometimes it feels like it's the real mission."

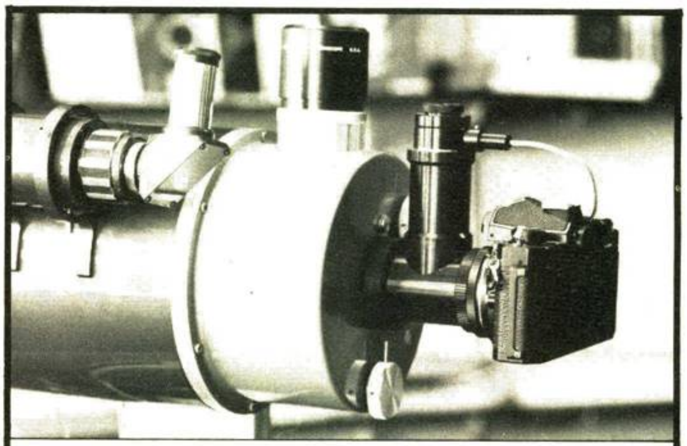
There are three phases to the simulations: launch, orbit, and re-entry. During the countdown, the Houston Mission Control Center simply monitors. The launch control center at Kennedy Space Center in Florida is responsible for the countdown and getting the spacecraft to a liftoff condition. Once launched, Houston Mission Control takes over.

"The level of activity here is quite high," said Frank. "A lot of things are happening; a lot of different events occur, and we are monitoring those to verify that the vehicle is working correctly."

During the re-entry phase, it is Mission Control's main goal to see that the spacecraft guides itself through the difficult re-entry phase and that the vehicle is performing as expected. If it is not performing well, Frank said, it is Mission Control's responsibility to come up with the best technique for solving the problem.

Frank said Mission Control is not yet ready for the flight, but "we will be ready when we are needed. We will be there when the vehicle is."

Unfortunately, that may not be for some time. The latest estimates are that current problems — including those with the thermal tiles so important for re-entry and the main propulsion engines — may delay the initial launch still more, until early 1981.



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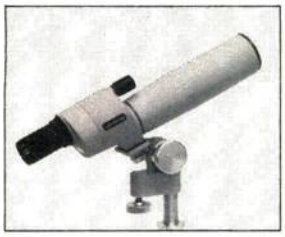
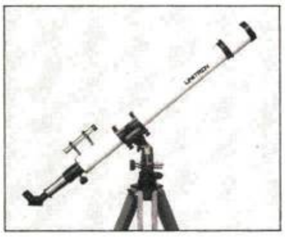
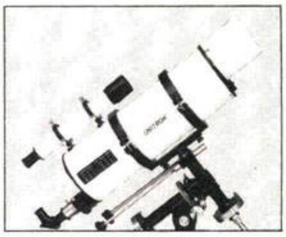


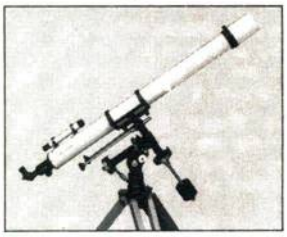
2.4 Refractor Telescope



4" Compact Refractor



3" Refractor Telescope



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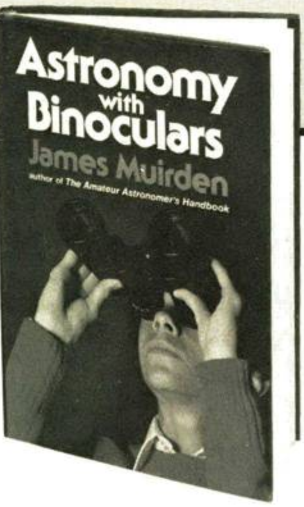
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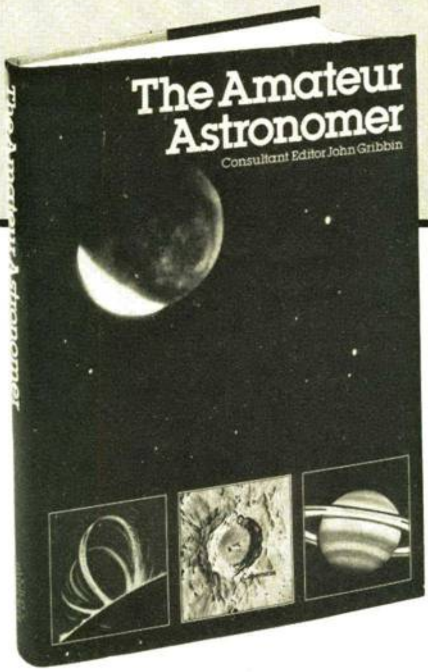

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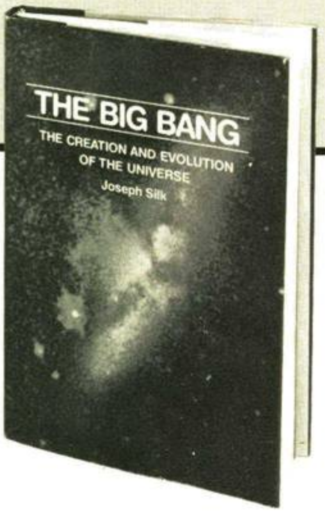

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KAO MISSION INCREDIBLE

by Ben Mayer

"We've got to be sure," the intense man in the sailor's watch cap said softly. He spoke with an English accent.

"As always, I'm sure it's going to be difficult to be sure," came the reply from the Canadian squatting on a footstool in front of the video screen.

"Off source, west!" the third member of the team commanded, his eyes riveted to the squiggly line on the chart recorder.

"We're off," the tracker operator replied.

"There's a definite shoulder here," said the investigator from his cramped position between the two large racks loaded with electronic equipment. "Look at this; it drops right down!"

The Englishman left his position near the strange-looking instrument mounted on the pressure bulkhead, connected with countless cables and tubes to the electronic consoles. Motionless, deep in thought, he stared at the monitor where a stepped graph was displayed full-screen in phosphorescent emerald.

"Looks good," he allowed. "Back on source."

"Roger."

The new day, September 29th, was barely an hour old and the Sun was setting. Takeoff had been at 00:58 UT. The spectacular sunset unfolded in slowest motion since we were chasing the solar disk as it gradually faded in the cloud layer blanketing the Pacific. Although we would be flying nonstop for eight hours, now toward Hawaii, our destination was also our point of departure: NASA's Ames Research Center at Moffett Field in Mountain View, California.

We were aboard the Kuiper Airborne Observatory (KAO), a unique craft which defies every preconceived notion concerning astronomical equipment. There are no steel and concrete foundations here, 41,000 feet above the Pacific Ocean, to tie telescope and mirror to unshakeable bedrock. No dome protects this telescope against merciless 500 mph winds of flight or unrelenting -60° temperatures of high altitude. Lacking even an equatorial mount, the system can only muster 40° of motion in altitude and a paltry 4° in azimuth.

This is no ordinary 36-inch telescope mounted in a giant jet transport. Rather it must be thought of as a sophisticated 91 cm Cassegrainian reflector with a swift aircraft attached *to it. The f/2 primary mirror of Cer-Vit* material and the A-frame supporting structure of Invar are barely affected by the extremes of temperature. Housed within the fuselage, just forward of the rakish wings of the Lockheed C-141, the telescope points at right angles to the direction of flight. It is supported on one side only and held to a main bulkhead with a spherical compressed air bearing which cushions motor vibrations and allows motion in two axes.

Everything quite literally revolves around the reflector and the "experiment" which is attached to it: the investigating astronomers, the five specialists needed to operate all systems and computers, the crew of pilot, co-pilot and flight engineer, a meteorologist and, finally, the aircraft itself.

"There's turbulence," the mission director reported to all flight members, as he typed the words into the terminal keyboard for the record. "Aircraft wallowing." Even as the ship cut the rolling air, the telescope compensated for every move. Pivoting first to the right in one jolting motion, it swung back quickly, making three or four rapid corrections in azimuth. Although the telescope — open to the elements in its forward cavity — was itself hidden from view, the cabin-side portion supporting the sensing devices could be watched as it performed a jerky round dance in quickstep.

Watching the "source" and the nearby guide stars through the low-level-light television zoom camera which was riding on the telescope, not a trace of tremor could be detected. The principal guiding monitor displayed the target star field powerfully magnified in a field of 18 x 25 arc-minutes, with crosshairs crisply superimposed on Chi Cygni, a variable star in the Northern Cross.

Flying north-northeast — now at an altitude of 41,350 feet — we were above 99% of the obscuring water vapor in the Earth's atmosphere. Only at these rarefied heights, beyond the mantle of moisture which shields our planet, can delicate sensors tune in to the secrets of infrared and shortwave radiations from outer space.

We had acquired our target star with the help of ADAMS (Airborne Data Acquisition and Management System), an onboard computer which has been programmed to remember over a quarter million stars to magnitude 9 or 10 and their coordinates. On command ADAMS can produce star maps which can be superimposed on the videomonitor, an invaluable aid when invisible radio sources are targeted and researched. ADAMS also generates the jet's flight path, constantly reports and displays aircraft and telescope performance data, and does "general housekeeping" *chores.*

Once again the investigating team had opened the shutter of their sensing detectors so that the incoming

NASA's giant C-141 telescope-carrying aircraft, the Kuiper Airborne Observatory, waits outside a hangar at Moffett Field.

radiation in the microwave range could be measured, recorded and plotted, then instantly reduced to graphs for display on the large green cathode ray monitor. The observing routine might have seemed dull to a casual observer ("Off source, south " — "On source " — "Off source, north ") as sensors gently stroked their way across clouds of carbon thousands of light-years away in space.

Suddenly the graph on the computer screen exploded into Manhattan skyscrapers over what — just a moment before — had been a low horizontal landscape. "Wonder what that means," the Canadian mumbled to himself. But his words were heard by most since all on board wear headphones with lip-microphones to permit instant communication over the roar of the jet engines.

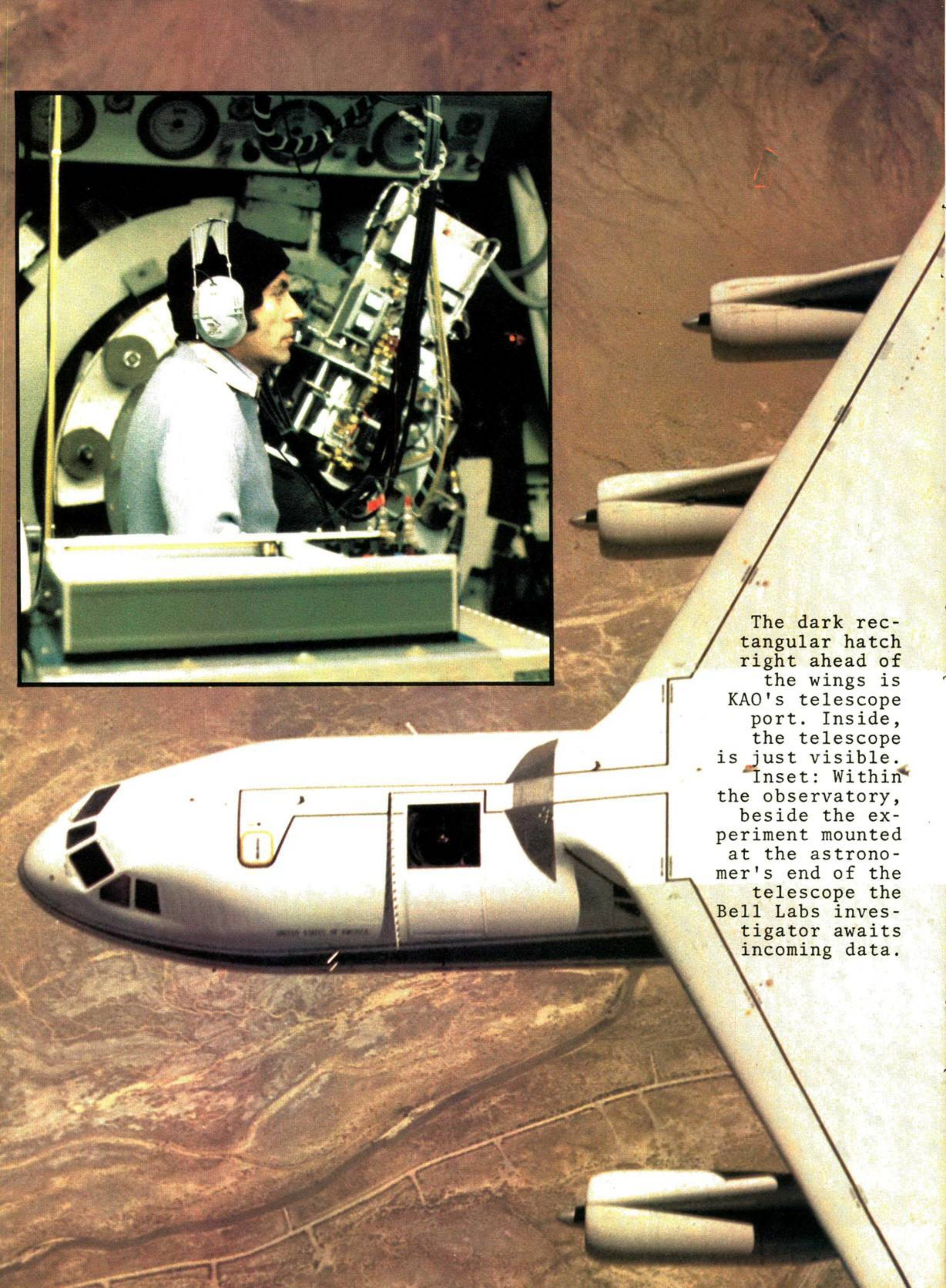
Plotters impatiently scratched nervous lines on slowly moving scrolls of graph paper. Line upon hurried line of data appeared onscreen on command, instantly translated into graphs. The drama of search was palpable as unforgetting memory cores yielded neatly graduated baselines and then erected vertical reference points with flawless spacing. One touch on the keyboard and yet another vertical zigzag would trace itself like slow green lightning on the magic screen, to remain there until a hard copier could produce a lasting graphic record of the tenuous image.

"Dammit — what happened?" the words burst over the intercom.

"The Exec has crashed," said the mission director and then, to the pilot, "Fly on manual; our main computer just crashed." Calmly the words came back: "Roger. But please don't say 'crashed'; that's not a good word." "Main computer down," the mission-director corrected, even as he typed the words "EXEC CRASHED!! UNKNOWN CAUSE" into the keyboard. A backup computer had already recorded the time in print — to the split second.

There was hardly time for the technicians to start tracing the cause of the problem because, as witnessed by the log entry, the "Exec" started functioning again after precisely 36 seconds as if nothing had ever happened. "ON SOURCE, COMPUTER BACK UP."

Telescope operators oversee the hundreds of details in an observing run. Inset: Six hours into the all-night flight, even astronomers show signs of fatigue.



The dark rectangular hatch right ahead of the wings is KAO's telescope port. Inside, the telescope is just visible. Inset: Within the observatory, beside the experiment mounted at the astronomer's end of the telescope the Bell Labs investigator awaits incoming data.

ADAMS' monitors are on display throughout the aircraft so that everyone, anywhere aboard has immediate access to status information in the constantly changing readout:

U.T.	6 19 15
LATITUDE	35 : 36 : 2
LONGITUDE	–136 : 33 : 4
ALTITUDE	41365
PITCH P1 & P2	.69
WINDSPEED	26.02
WIND ANGLE	299.83
TRUE HEAD	4.4
TRUE ROT	77.49
AIR MASS	1.10
OBJECT	X CYGNUS
TURN STAT	NO TURN
HEADING ERR	–.11
TELEV	65.127
I.R. AIR T	–54.3
Z H_2O VPR	6.0
B H_2O VPR	6.6
LAST BLOCK #	447
NOVA SCAN #	496

At first glance only the seconds on the top line seem to be changing. But closer scrutiny shows that even the slightest drift in altitude is registered immediately, as are position updates, wind information, and the all-important moisture content in the thin air outside the craft.

In the cavernous aft section of the plane, the meteorological expert gathers weather information and the water vapor data from his own consoles — all of which he furnishes to the principal investigators. In addition, this scientist is engaged in his own research program. As an expert on CAT (Clear Air Turbulence), the bane of pilots and air travelers, he is seeking new methods which will allow the timely forecasting of these destructive airquakes. His sensors are applied to the outside of the aluminum hull and report on conditions in the subfreezing hostile environment just inches away.

"You have only six seconds to get to your oxygen mask and put it on," the flight engineer had warned during the lengthy safety and emergency briefing before takeoff. "Keep your pressure regulator set at 100% oxygen at all times, and if you see any hydraulic leaks anywhere — it's a pink substance and shows up easily — report it to the mission director at once. Don't go near it. It's under 3000 pounds of pressure and the spray will cut skin like a knife."

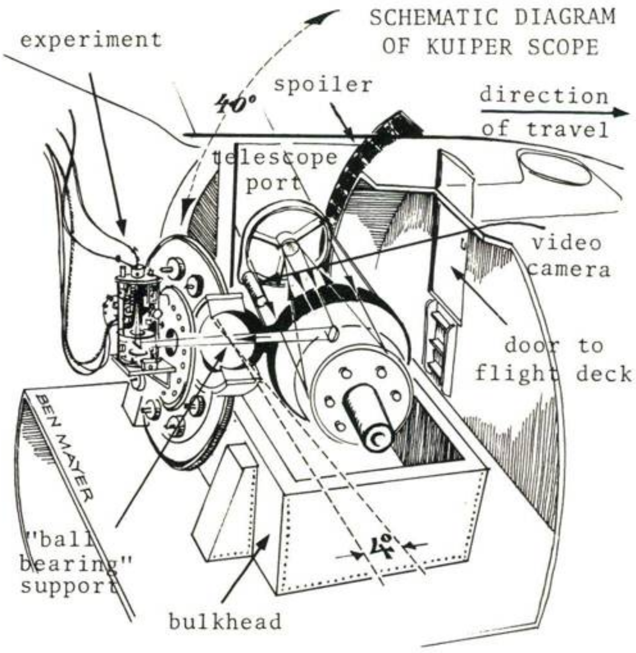
They take no chances aboard the KAO which is named after Gerard P. Kuiper, the late pioneer of airborne spectroscopy. Like its Learjet predecessor which carries a 12-inch gyro-stabilized telescope, the flying observatory is owned and operated by NASA. Strict disciplines of safety are taught to guest observers who come from universities or government agencies, as well as from abroad.

Tonight the experimentors were from Bell Laboratories, JPL, and New York University — an Englishman, a Canadian, and an American, respectively.

"I had expected the systems to be garbaging after the Exec went out," said the New Yorker.

"For a while there it looked like Chi Cygni was going down the drain. Perhaps there was something very good out there and we were not supposed to find it," replied the Canadian from JPL.

As it was, the consequences from the brief shutdown seemed to be minimal and another pass was made at the target. The hours of data-taking slid by. Then the aircraft began a new heading so that other sources could be acquired and scanned for the traces of neutral carbon — the quarry of the researchers for three flights now. This flight, the fourth, was their last. At the beginning of the mission the team seemed lost to the world, going about their tasks with dedicated but unsmiling precision, but with the flight nearing completion, there now was an air of relaxation, even levity. This had been no ordinary quest, no esoteric exercise that would widen no horizons. Here the ultimate talents of gifted scientists were combined with state-of-the-art technology in pursuit of the tenuous beginnings of stellar formation, the very birth of suns. A NASA screening committee would not lightly grant the costly resources of the Kuiper Airborne Observatory for one-twentieth of the eighty or so annual flights unless it were in pursuit of fundamental scientific truths which could enlighten mankind.



These were men who designed their own experiments, built their own incredible sensing devices, flew their own missions, and operated equipment for which no manuals yet exist. Here are the seekers — in quest of what may be beyond human sight but not their scientific vision.

Rather than flaunt the extraordinary success and discoveries of the mission, these modest men of science would confine their moments of silent triumph to a predawn phone call to a loved one, telling them — rather than the sleeping media — of carbon-bearing Manhattan skylines over hitherto horizontal pastoral profiles.

Much work still lay ahead — but inferences of theoreticians had been proved. Ever since Galileo, it was proof alone which would compel the mind to accept the truth and truth underlies science.

The "Kuiper" made its landing approach at 2:45 in the morning. "Military Cargo approaching from west," some air traffic controller broadcast. "Military Cargo, indeed!" mimicked our pilot without pressing the transmit button. We landed on the deserted Moffett Field runway and taxied to the vast hangar where the aircraft was housed between flights. The scientists unloaded their heavy equipment themselves. Then at 4:30 in the morning in an unfriendly neon-lit corridor of the hangar building, a bottle of Johnny Walker materialized. Ice cubes from a photographic plate storage refrigerator were dispensed, two per paper cup, while tired but relaxed banter was exchanged.

"To carbon," the modest Englishman proposed the toast.

"To carbon!" echoed the crew, before they called it a night.

Ben Mayer, a well-known Los Angeles "star-friend," was allowed to fly as an observer aboard KAO during a research flight last fall.

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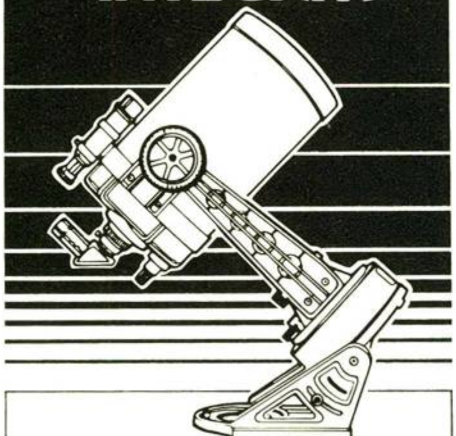

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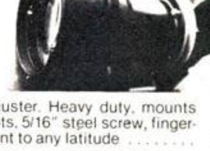

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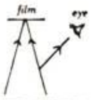

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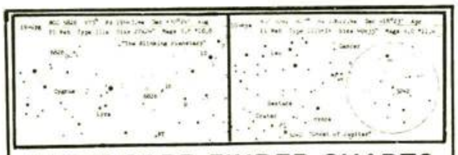

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WANTED — Parts list, schematics and PC board templates required to construct an electronic sidereal clock using stock electronic store parts. Prefer battery operated. Write Jeff Meyer, Moffatt Rd., Cold Spring, NY 10516.

WANTED — The eye can see things the camera cannot. I'm into visual astronomy. Want Dynamax 8 (preferably) or Celestron 8, with tripod, wedge; camera optionals not needed. Will pay cash and shipping for reasonable deal. Contact John Mood, 4812-1/2 Del Mar, San Diego, CA 92107. Phone (714) 225-9639.

WANTED — Guidescope. Need 4-6" Cassegrain, Schmidt-Cassegrain, or Maksutov optical tube assembly only. No mount or eyepieces wanted. Special consideration for Celestron 5. Contact Christian Pierson, 4090 Fairway Dr., Port Huron, MI 48060. Phone (313) 385-9247.

WANTED — I'd like to hear from people doing interesting things in astronomy with microcomputers/microprocessors (TRS-80, PET, APPLE, etc.). Data acquisition, measurements, controls, data processing. Contact Jon Titus, Box 242, Blacksburg, VA 24060. Phone (703) 951-2684.

ANNOUNCEMENT — The Calumet Astronomical Society meets on the 2nd Monday of each month at 7:30 p.m. at the Griffith Public Library, 940 N. Broad St., Griffith, IN. Phone (219) 663-8942.

ANNOUNCEMENT — The Jackson Astronomical Association meets on the 1st Friday of each month at 7 p.m. at the Mississippi Museum of Natural Science located at 111 N. Jefferson St. For additional information contact Ben Hudgens, 505 Woodstone Rd., Clinton, MS 39056. Phone (601) 924-4705.

ANNOUNCEMENT — The Federation wants you! Join Starfleet, an international nonprofit organization based on the federation military fleet presented on Star Trek. Please write Mike Lyons, 5977 Houston, Parma, OH 44130.

ANNOUNCEMENT — National Convention for Aviation and Space Education, held July 19-27, at Florida Institute of Technology and Kennedy Space Center. Contact American Society for Aerospace Education, 1750 Pennsylvania Ave. N.W., Washington, DC 20006. Phone (202) 347-5187.

ANNOUNCEMENT — 33rd Annual Convention, N.W. Region, Astronomical League. August 2-3, Whitworth College, Spokane, Wash. Hosted by the Spokane A.S., meeting features papers, slide presentations, telescope displays, astrophoto exhibits, flea market and banquet. $6.00 individual, $7.50 family; dormitory rooms and cafeteria available. Contact Ted Young, E. 11015 Rockwell Ave., Spokane, WA 99206.

ANNOUNCEMENT — The Pocatello Astronomical Society meets on the 2nd Thursday of each month at 7:30 p.m. in the Community Room of the Pocatello Public Library. The public is invited. For information call (208) 232-7251.

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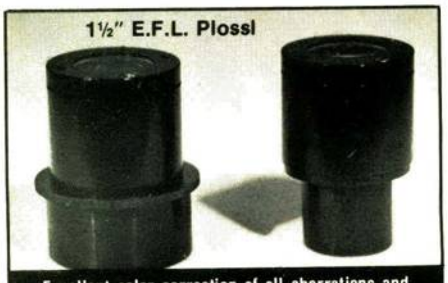

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close-up on centaurus/crux

through the eyepiece

June's feature event is a beautiful conjunction of Venus and Mercury on June 1st, followed by a fine appearance of Mercury in the evening sky. Nor is this all: Look for occultations of Regulus and Saturn by the Moon, Neptune at opposition — and, of course, Jupiter and Mars offer their usual delights.

Mercury

In June, Mercury puts on one of its best performances all year. Besides Mercury's good apparition overall, Venus — which is moving swiftly down toward the horizon — will pass less than a degree south (left) of Mercury on the evening of June 1st. For once, locating the elusive inner planet will be very simple.

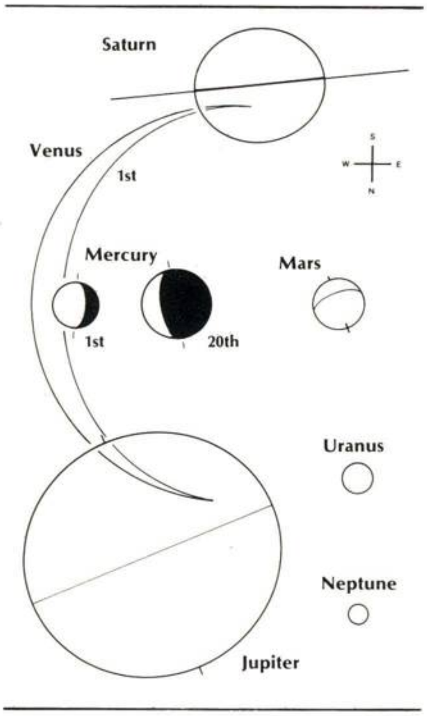
If you go out to look for Mercury 45 minutes after sunset (when the sky is usefully dark) and if you can see down to 5° above the horizon, then Mercury will be visible from May 26th until June 21st. Greatest elevation lasts from June 5th to 9th; greatest eastern elongation comes on the 14th. (See the alt/az diagram on page 80.)

During the month (roughly speaking) that Mercury is visible, its phase will alter from nearly "full" (82% lit) on May 26th through 50% (the "half-moon" phase) on the date of elongation down to 26% lit on June 21st. Over the same dates, its angular size changes from 5.6" (May 26th) to 8" (June 14th) to 9.3" (June 21st). Haul out your telescope every clear evening and take a look; opportunities like these don't come very often.

Venus

Winding up its evening appearance this month, Venus crosses into the morning sky via inferior conjunction on June 15th. Disappearing from the western sky into the Sun's glare around the 7th or 8th of June, Venus will reappear low in the east-northeast before sunrise during the last week of June.

Locating it after the Sun has set or before it has risen is pretty easy; more fun — and more challenging — is finding Venus during the daytime. It may sound difficult or even impossible, but isn't; here's how you do it:



To start with, you'll need to know the positions of the Sun and Venus for the day in question. This information is tabulated daily in the *American Ephemeris & Nautical Almanac* (your library should have a copy), but we'll give you the data for a couple of dates below.

Take the figures and subtract Venus' position from that of the Sun. This will tell you how far east or west and north or south from the Sun Venus lies.

The other item you need (or will find very useful) is an equatorial mounting, preferably with setting circles.

The actual procedure is simplicity itself — since finding the Sun is easy enough, you begin by centering it in your eyepiece *(use projection methods and be VERY careful!!)*. Then offset the distance you worked out earlier — so much in R.A., then so much in Dec. — until you arrive at Venus. (A red filter will darken the blue sky and help reveal Venus.)

If your scope hasn't got setting circles, you'll have to guess how far to move it, based on the size of your eyepiece's field of view.

On June 10th, Venus lies 9° west (36^m of R.A.) and half a degree north of the Sun; on the 15th, Venus will have the same right ascension as the Sun and be a degree south of it (this is inferior conjunction); and on the 20th, Venus can be found 7.8° (31^m of R.A.) west and 2.5° south of the Sun.

Moon

In the late afternoon and early evening of June 17th, a 5.1-day-old Moon will occult Regulus (Alpha [α] Leonis), the first magnitude star in Leo's forequarters. The event will be visible at locations southwest of a line between New Orleans, Louisiana and Olympia, Washington, starting in the west at about 00:00 hours UT, June 18th.

A day and a half later, at around midday on June 19th, the Moon will occult Saturn, as seen from locations in the Midwest eastward.

Both of these events will occur in daylight or twilight for most observers, so they won't be too easy — but give it a try anyhow.

The June winner of our monthly "Best Astro-Photo" Award is Lee Coombs' splendid shot of M-31, the Great Galaxy in Andromeda. Carefully guiding his 10-inch f/5 Newtonian telescope, he exposed blue-sensitive 103a-O spectroscopic film for fifteen minutes at the instrument's prime focus.

universal time

Astronomers the world over use an unambiguous system of time reckoning based on a 24 hour clock, called Universal Time (UT). Times in Through the Eyepiece are UT unless noted otherwise. To convert UT into your local daylight time, subtract the following number of hours for each time zone: EDT, 4; CDT, 5; MDT, 6; PDT, 7; Alaska and Hawaii, 9. For example, if an event is to happen at 03:00 hours UT on June 7, then the time in EDT would be 11 p.m. June 6. Likewise, 03:00 UT on Sept. 2 becomes, in PDT, 8 p.m. on Sept. 1.

Mars

Having finished its triple conjunction with Jupiter, Mars this month will appear to hasten eastward out of Leo. On the 25th, it'll overtake Saturn, passing 1.7° to the south and appearing slightly brighter (Mars will be at magnitude +1.1, Saturn at +1.3).

On this same date, Mars' apparent diameter will be 6.4" and its distance 218 million kilometers (135 million miles). It is currently summer in the martian northern hemisphere, and we are looking down on about the 25° N parallel of latitude.

Asteroids

1 Ceres, emerging from the blaze of light from the Sun (it was at superior conjunction on May 18th), lies in the morning sky at $4^h\ 28^m\ 22^s$, +19° 24′ 01″ (1950 coordinates) on the 15th. This places the 8.4 magnitude object in Taurus, directly north of the Hyades Cluster — a region that rises but a short time before the Sun.

2 Pallas is in Cetus ($1^h\ 28^m\ 51^s$, +2° 13′ 22″ on the 15th, 1950 coordinates, at magnitude 9.5) somewhat to the west of Ceres in the morning sky, but its lower declination means that it, too, won't rise until just before the Sun does.

3 Juno, on the other hand, lies in the evening sky on the Cancer-Leo border. This area sets about midnight local daylight time on the 15th of June when the magnitude 10.0 asteroid's position is $9^h\ 10^m\ 46^s$, +13° 09′ 32″

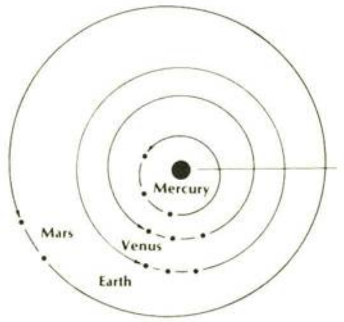
Moon Data:

Last quarter	June 6 at 2:53
New moon	June 12 at 20:38
First quarter	June 20 at 12:32
Full moon	June 28 at 9:02
Last quarter	July 5 at 7:27
Perigee: June 9 at 4h	367,630 km
Apogee: June 21 at 6h	404,184 km

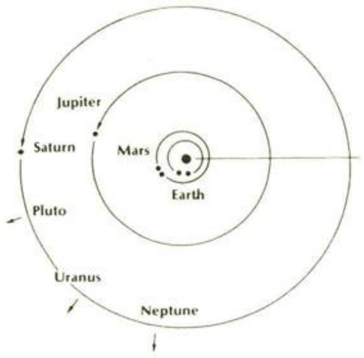
Planet Finder

Planet	Date	R.A. (1980.5)	Dec.	Mag.	Distance (AU) from Earth	Distance (AU) from Sun
Mercury	10	$6^h57.7^m$	24°27.7′	+0.4	0.90	0.41
	20	$7^h36.8^m$	21°33.7′	+1.1	0.73	0.45
	30	$7^h45.9^m$	18°38.1′	+1.9	0.61	0.47
Venus	10	$5^h49.4^m$	23°30.1′	-3.1	0.29	0.73
	30	$5^h05.1^m$	18°50.9′	-3.8	0.32	0.73
Mars	15	$11^h11.8^m$	6°07.6′	+1.1	1.39	1.61
Jupiter	15	$10^h24.1^m$	11°11.1′	-1.5	5.68	5.42
Saturn	15	$11^h29.2^m$	5°44.5′	+1.3	9.48	9.47
Uranus	15	$15^h19.3^m$	-18°04.9′	5.9	17.88	18.75
Neptune	15	$17^h22.2^m$	-21°44.6′	7.6	29.26	30.28
Pluto	15	$13^h35.0^m$	8°48.5′	14.0	29.70	30.14

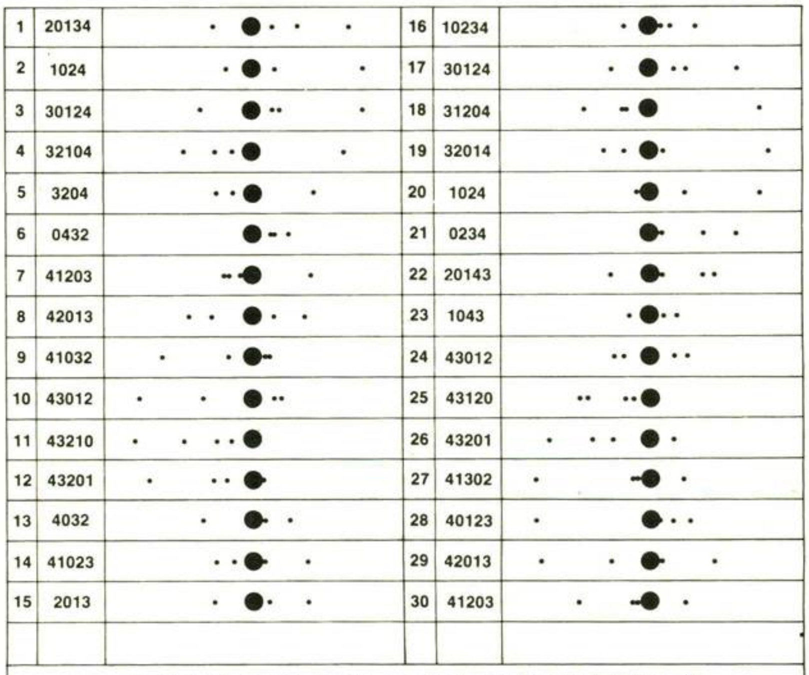
Inner Solar System



Outer Solar System

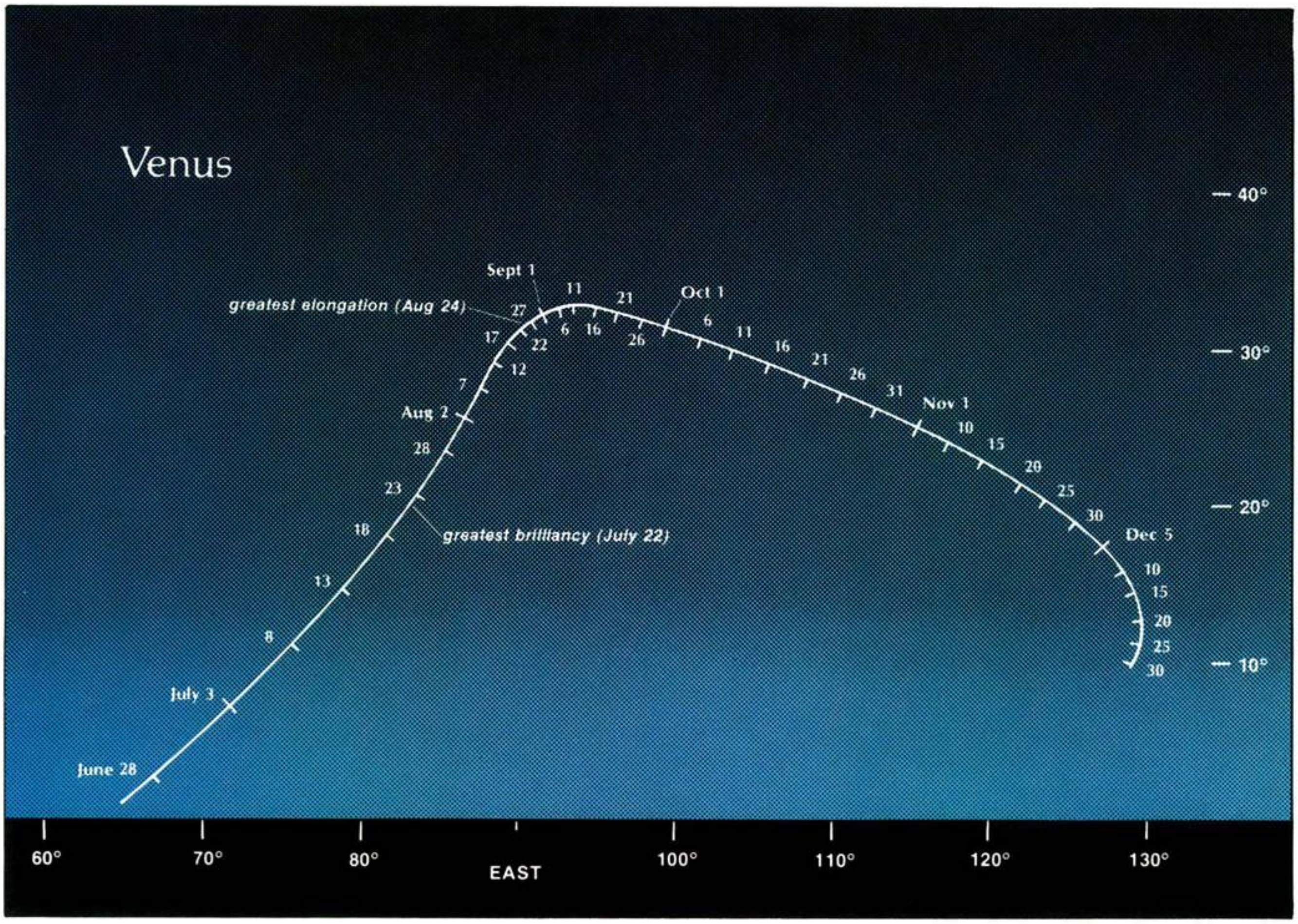


satellites of jupiter 04:00 ut



1	20134	16	10234
2	1024	17	30124
3	30124	18	31204
4	32104	19	32014
5	3204	20	1024
6	0432	21	0234
7	41203	22	20143
8	42013	23	1043
9	41032	24	43012
10	43012	25	43120
11	43210	26	43201
12	43201	27	41302
13	4032	28	40123
14	41023	29	42013
15	2013	30	41203

Jupiter = 0, Io = 1, Europa = 2, Ganymede = 3, Callisto = 4
(South is at top, matching the view in a telescope.)



The path taken by Venus in the morning sky for the rest of the year is shown above. The time is three-quarters of an hour before sunrise, and although the diagram assumes you are observing from 40° north latitude, you'll see much the same view from anywhere in middle-northern latitudes.

(1950).

4 Vesta is in conjunction with the Sun on June 25th, so forget about searching for it.

Jupiter

Jupiter, "abandoned" by Mars near Regulus, will slowly slip eastward along the ecliptic away from the star. Moving less than 10° a month, Jupiter can't outrace the encroaching twilight which will catch up to it in August.

Noticeably smaller in size than at opposition (35" equatorial diameter at midmonth as opposed to February's 45"), Jupiter is still an excellent target for observers. Even when it is near conjunction with the Sun, its large size guarantees you a worthwhile view — unlike Mars, for instance, which you must catch near opposition if you want to see any surface details.

Saturn

When Mars hustles past Saturn on the 25th, the ringed planet will have an apparent equatorial diameter of 17.3", its magnitude will be +1.3, and its distance, 1,436,000,000 kilometers (890,000,000 miles). Or to put the last figures another way, Saturn will be 80 light-minutes away.

The rings will remain invisible (or all but so) through June. Earth is still about a degree south of the saturnian ring plane while the Sun lies nearly 2° to the north of it. This means that when we do cross over onto the rings' northern side late next month, they will appear very abruptly.

Uranus

Uranus, a month past opposition, will be easy to find at magnitude 5.8 if you search 1° south and 3° west of 5.6 magnitude Zeta (ζ) Librae. Look for a small, round disk 3.8" in diameter.

Neptune

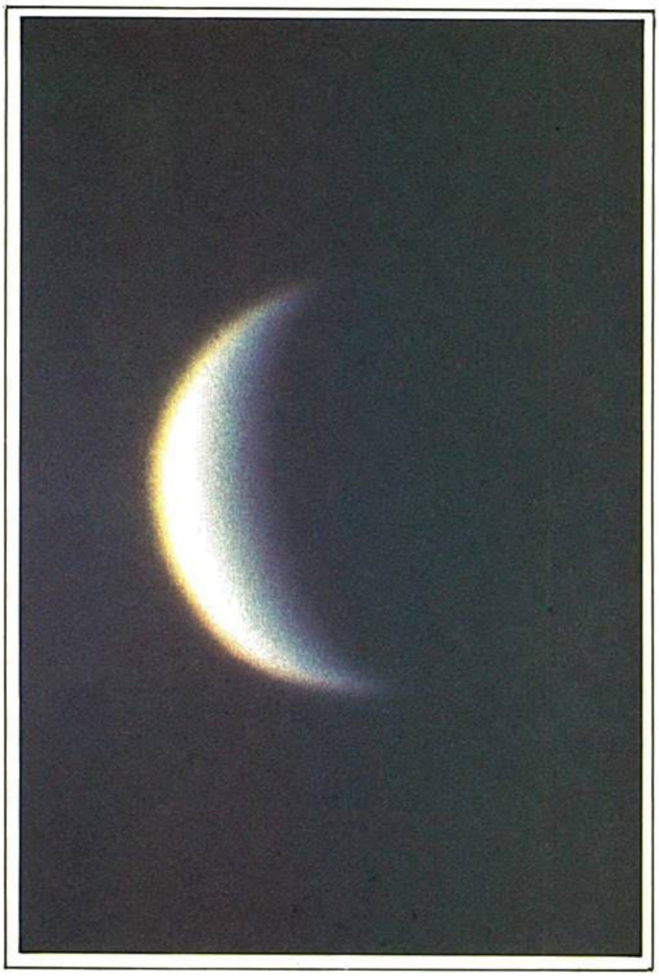
Arriving at opposition on June 12th, a month after Uranus, Neptune is a 7.7 magnitude object having an apparent diameter of 2.5". It is located in southern Ophiuchus about half a degree south and the same amount east of 4.5 magnitude Xi (χ) Ophiuchi. You won't see very much, even through a big telescope: though large — Neptune's a gas giant, after all — it's just too far away.

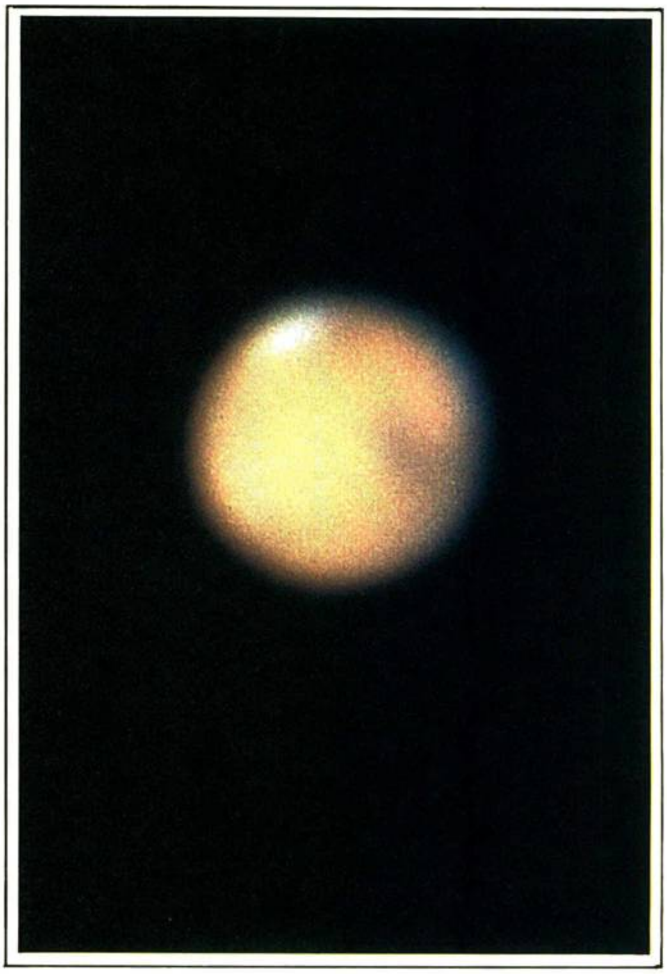
close-up on centaurus/crux

The southern constellations Centaurus and Crux are invisible to most of our readers, but together they encompass one of the richest and most exciting regions in the whole sky. A survey of the telescopic treasures hidden away just below the southern horizon is nearly enough to make most northern hemisphere observers rush out and book a flight to some point south of the equator where these riches ride high in the sky at this time of year. Remember, though, June brings the beginning of winter to the southern hemisphere, so don't fly too far south!

Crux, better known as the Southern Cross, is one of the most striking asterisms in the sky. Three of its stars, Alpha (α), Beta (β), and Gamma (γ), are among the brightest thirty stars in the entire heavens, and the cross or kitelike arrangement is more compact — only 7° high — than the Northern Cross (Cygnus the Swan), which is more than 20° long.

Crux was originally a part of the much larger constellation **Centaurus**, of which at least a part manages to rise above the southern horizon for all of the continental United States. Unfortunately, though, most of its





exciting deep-sky objects and double stars lie too far south for American observers, except those in Hawaii and southern Florida and Texas.

NGC-3766 is a pleasing open cluster containing more than 50 stars ranging from eighth to thirteenth magnitude packed into an area 10 minutes of arc across. The beauty of this rich, fairly compact cluster would have earned it more fame if it were located in northern skies.

The planetary nebula **NGC-3918** is famous for its "beautiful rich blue" color, as John Herschel described it. Its small size — visual estimates range from 10 to 13 seconds of arc — and featureless disklike appearance have led to its being compared with the planet Uranus, although at eighth magnitude it is considerably fainter. Perhaps a good nickname for NGC-3918 would be "the Ghost of Uranus."

Alpha (α) Crucis, the first magnitude luminary of Crux and the fourteenth brightest star in the sky, is also known simply as Acrux. It happens to be a particularly pleasing double star system consisting of two second magnitude brilliant B-type stars separated by a close 4½ arc-seconds. Intrinsically thousands of times more luminous than the Sun, the distance to these stars is so great (nearly 400 light-years) that virtually no orbital motion has been detected. Each of the two components seems to be a close double itself, according to spectroscopic analysis.

Gamma (γ) Crucis is another double in the Southern Cross, but in every way very different from Acrux. First, it is not even a true binary system but instead only an apparent double, for the 6.7 magnitude secondary lying at a distance of 111" (position angle 31°) is not physically connected with the primary. The more brilliant member of this optical pair is an M-type red giant, while its apparent companion is a white A-type star, providing an interesting color as well as magnitude contrast.

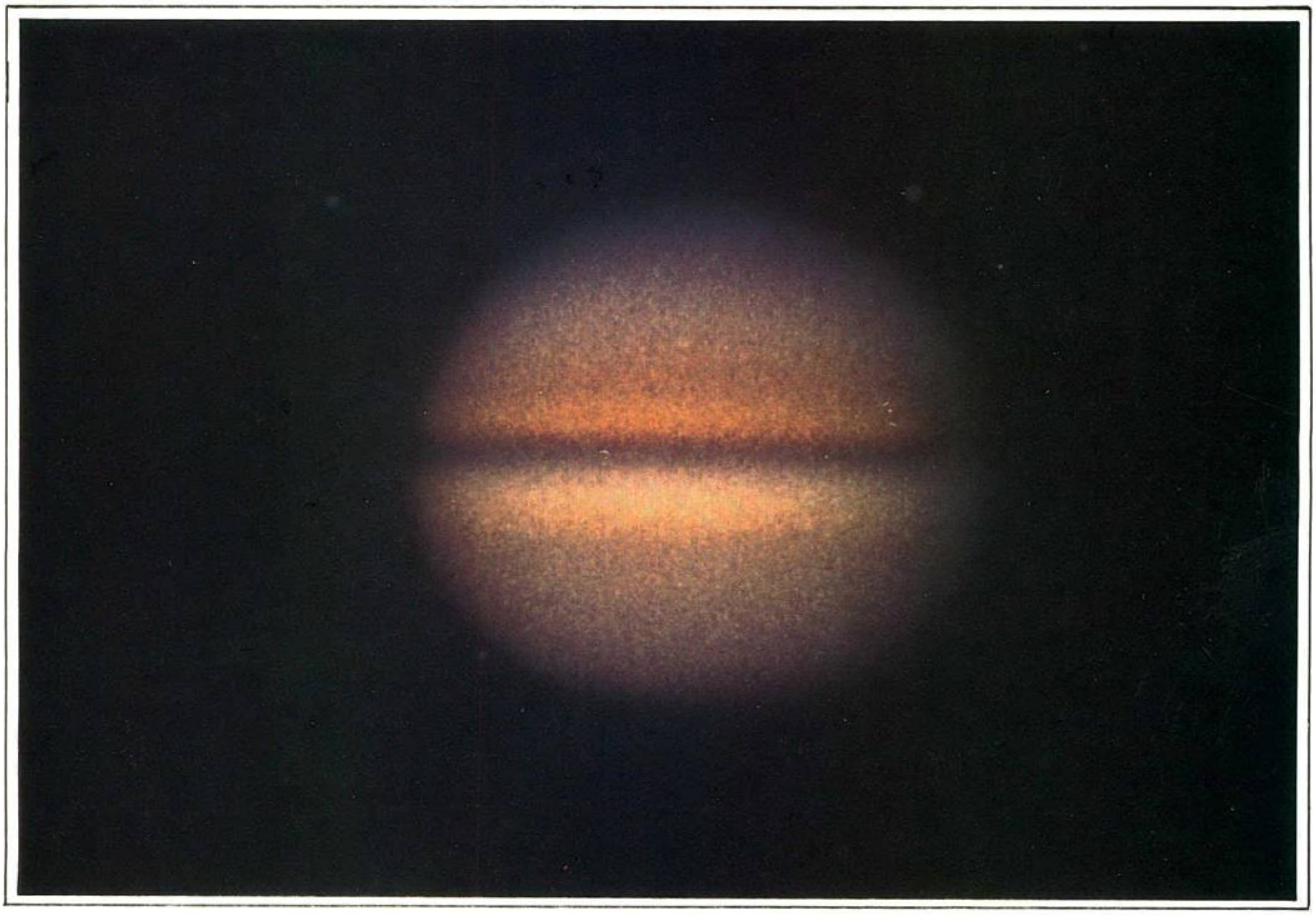
The perfectly matched double **Gamma (γ) Centauri** presents the telescopic viewer with two A0-type stars nearly identical in brightness and color — white. The pair, however, is very close, separated at present by less than 1½ seconds of arc. This separation is currently decreasing toward a minimum of only 0.2" at periastron (closest approach) in 2016.

One of the greatest treasures of the southern sky — or of the entire sky, for that matter — is **Kappa (κ) Crucis**, thanks to John Herschel also known as the Jewel Box. This magnificent galactic cluster is crowded into a relatively small area 10 minutes of arc across. A very young cluster with a large number of highly luminous supergiant members, most of the stars are blue-white to white in color with a smattering of red stars for a pleasingly colorful effect.

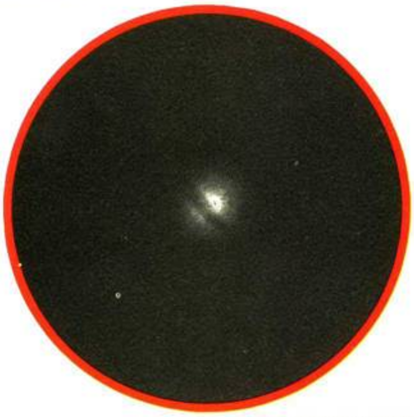
The edge-on spiral galaxy **NGC-4945** appears as a faint blurry spindle about 12′ long in a moderate (6-8 inch) telescope. Fairly bright at magnitude 9.2, the glow is fairly uniform, with virtually no structure visible. Because this spiral is seen almost exactly edge-on, its precise classification is in doubt, and it may be a barred spiral. In either case, it is thought to be fairly open (type c).

Among its many wonders, Centaurus also contains one of the most mysterious objects in the sky. This is the giant peculiar galaxy **NGC-5128**. One of the largest and most luminous galaxies known, NGC-5128 is also a

Here are four of the five currently visible naked-eye planets — only Mercury is absent — looking much as they do at present. Venus (above left) was photographed by Charles Capen in 1964, Mars (above right) and Jupiter (top right) by D. C. Parker earlier this year, and Saturn (bottom right) by Charles Capen again, in 1966.

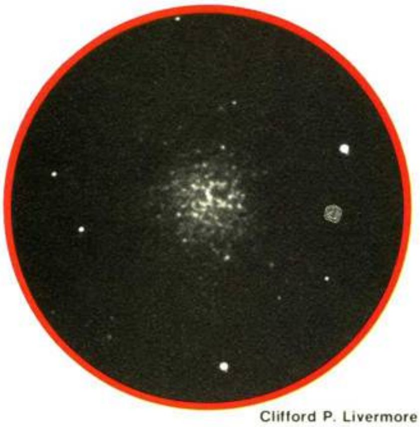


NGC-5128



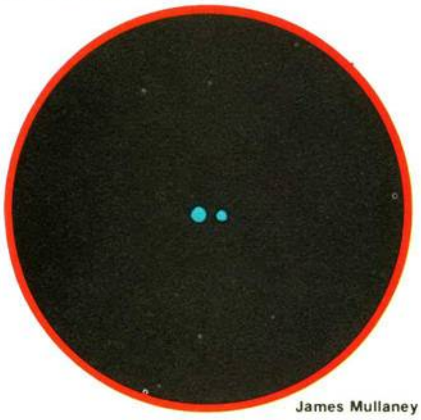
Dewey Schwartzenburg

Omega Centauri



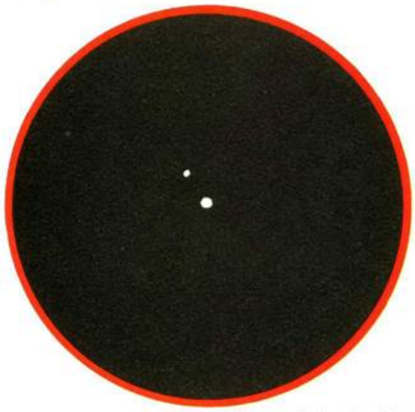
Clifford P. Livermore

k Centauri

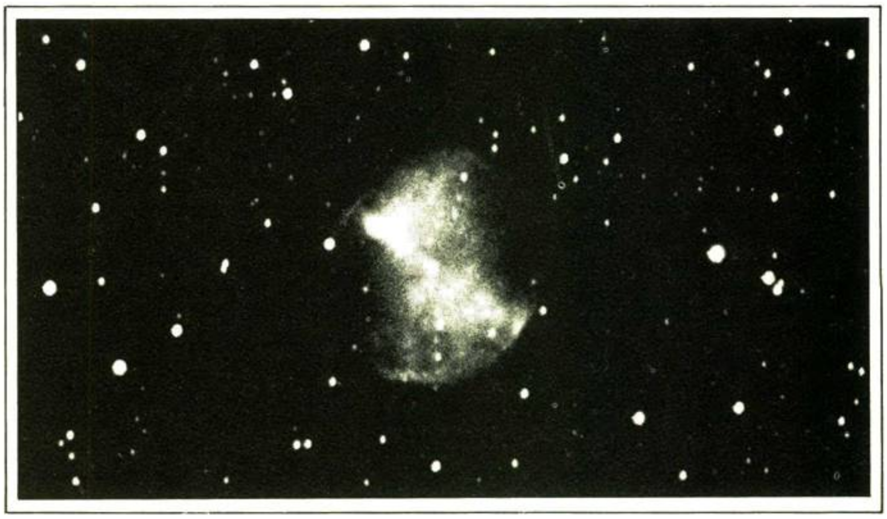


James Mullaney

Alpha Centauri



Dewey Schwartzenburg



M-27, the Dumbbell Nebula in Vulpecula, is a bubble of gas surrounding a faint, very hot dwarf star. In most telescopes the nebula appears oval, but Robert Luffel's photo brings out its hourglass shape nicely. He used an 8" f/10 scope, 103a-F film, and a half-hour exposure from a site in the Rocky Mountains.

strong source of radio emission under the name Centaurus A. It appears to be an elliptical galaxy, but unlike other ellipticals, a dark lane of obscuring material appears across it. This dark band is clearly visible in instruments of moderate aperture (6-8 inches). It is clear that some highly energetic, but as yet unknown, process is going on in NGC-5128, giving rise to the intense radio emission and perhaps accounting for the obscuring lane as well. (For a striking view of this strange system, see the photograph on page 4, ASTRONOMY, February 1980.)

Omega (ω) Centauri is the brightest and most spectacular of all globular clusters, but its southerly declination makes it visible only in the southernmost parts of the United States. Our photograph was taken by Clifford P. Livermore from the summit of Mauna Kea (13,796 feet) on the island of Hawaii.

T Centauri is a semi-regular variable star which ranges from a maximum magnitude of 5.5 down to a minimum of 9.0 or even fainter with an average period of 91 days. Its spectrum shows a number of emission lines, and it appears to be a red giant. T's reddish color will be most apparent when it is at or near maximum light.

A pair of hot, B-type stars constitute the pleasing double star **k Centauri**. The two stars, separated by 8 seconds of arc in position angle 108°, share a common proper motion and are therefore moving through space together.

Beta (β) Centauri, also known as Hadar, is one of the brightest stars in the sky. It also happens to be highly luminous, more than 10,000 times as bright as the Sun, and is classed as a blue giant of spectral type B1. Its companion is a much dimmer 4.1 magnitude star located only 1.4" away, and is difficult to distinguish at such a close distance in the glare of the primary.

NGC-5460 is a large, fairly sparse open cluster occupying an area as large as the full moon. Of total integrated magnitude 6.3, it is composed of a few dozen individual stars no brighter than eighth magnitude. A low power, wide-field eyepiece, or even better a richest field telescope, is necessary to see this cluster at its best.

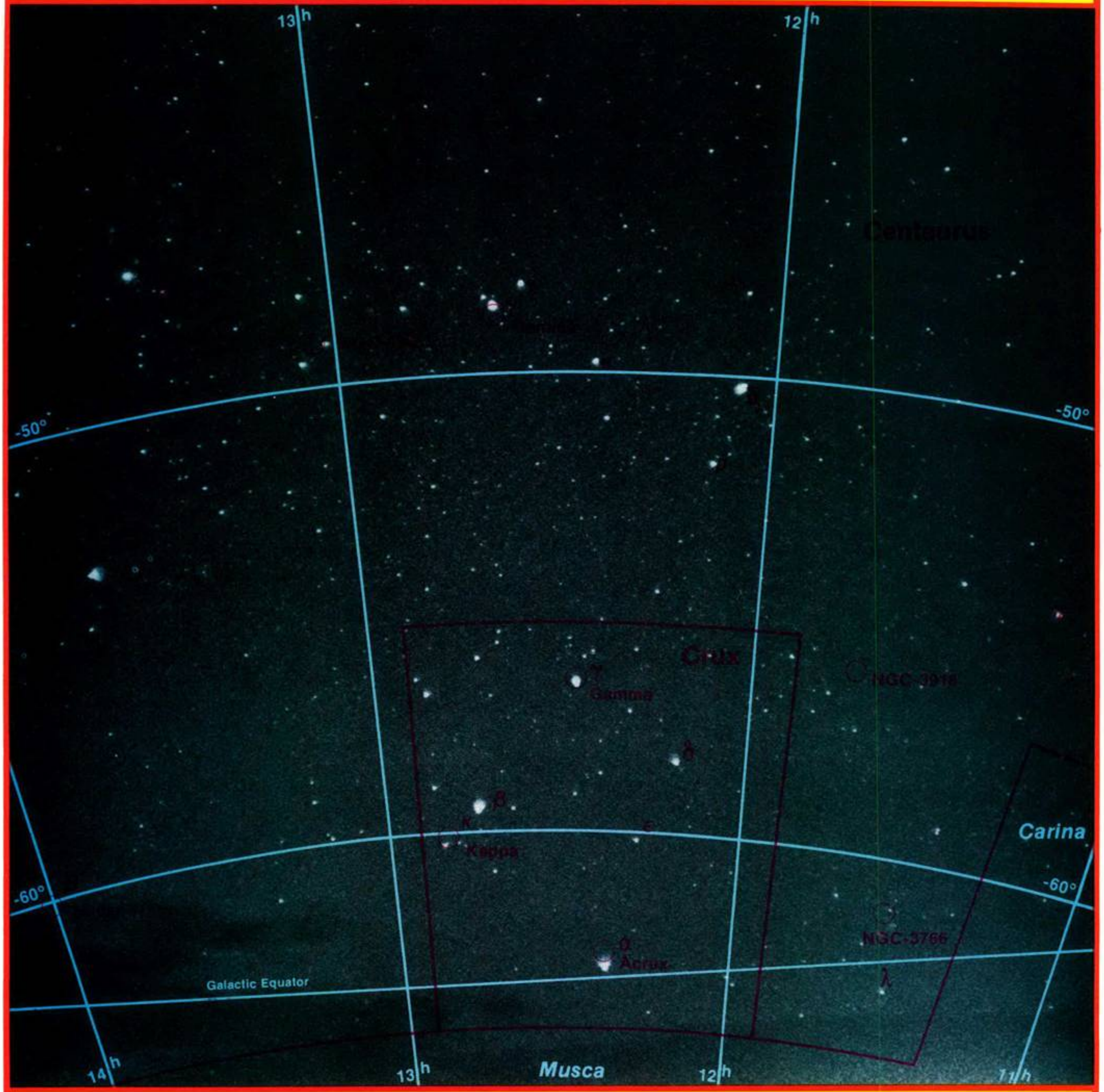
The long-period variable **R Centauri** is peculiar in having two distinct maxima and minima in each period. In a way its unusually long period of 548 days may be regarded as a double of a true period of 274 days duration, bringing it more into line with other such variables. Like other Mira-type variables, its color is deep red, and at greatest maxima it reaches naked-eye visibility, though the precise magnitude value varies.

A telescope reveals **Alpha (α) Centauri**, the nearest star to our Sun, as a double star. The primary is almost exactly three times as bright as the secondary, with a subtle color contrast thrown in. Sometimes called Rigel Kentaurus, Alpha Centauri is in fact a triple system, with a third component located an enormous distance away. This member of the system, which is believed to be in actual physical association with A and B, is slightly closer to our Sun than either of the other components. Since it is actually the nearest of all stars to us, it is therefore called Proxima Centauri. Proxima is a red dwarf, and having a diameter only one-twentieth that of the Sun, it is one of the smallest stars known. The planet Jupiter is twice as large, in fact, although the mass of Proxima is certainly much greater.

Map by Dewey Schwartzenburg

centaurus/crux

Photo by John Sanford


13h
12h
Centaurus
-50°
-50°
Crux
γ
Gamma
NGC-3918
δ
β
κ
Kappa
ε
Carina
-60°
-60°
NGC-3766
α
Acrux
λ
Galactic Equator
14h
13h
Musca
12h
11h

Object	Type	Mag.	Size/Sep. Per.	R.A. (1950)	Dec.	R.A. (1980)	Dec.
NGC-3766	○	5.1	10′	11^h34^m	-61°19′	11^h36^m	-61°29′
NGC-3918	■	8.4	13″	11^h48^m	-56°54′	11^h49^m	-57°04′
Alpha (α) Cru	★²	1.6,2.1	4.5″	12^h24^m	-62°49′	12^h25^m	-62°59′
Gamma (γ) Cru	★²	1.6,6.7	111″	12^h28^m	-56°50′	12^h30^m	-57°00′
Gamma (γ) Cen	★²	3.1,3.2	1.4″	12^h39^m	-48°41′	12^h40^m	-48°51′
Kappa (κ) Cru	○	5.2	10′	12^h51^m	-60°05′	12^h52^m	-60°15′
NGC-4945	§S	9.2	12′x2′	13^h02^m	-49°01′	13^h04^m	-49°11′
NGC-5128	§0	7.2	10′x8′	13^h22^m	-42°45′	13^h24^m	-42°54′
Omega (ω) Cen	●	3.7	30′	13^h24^m	-47°03′	13^h26^m	-47°12′
T Cen	m★	5.5-9.0	91^d	13^h39^m	-33°21′	13^h41^m	-33°30′
k Cen	★²	4.7,6.2	8″	13^h49^m	-32°45′	13^h51^m	-32°54′
Beta (β) Cen	★²	0.9,4.1	1.4″	14^h00^m	-60°08′	14^h02^m	-60°17′
NGC-5460	○	6.3	30′	14^h05^m	-48°05′	14^h06^m	-48°14′
R Cen	m★	5.4-11.8	548^d	14^h13^m	-59°41′	14^h15^m	-59°49′
Alpha (α) Cen	★³	0.0,1.2,10.7	20″	14^h36^m	-60°38′	14^h38^m	-60°46′

★	*Star*
★²	*Double Star*
★³	*Triple Star*
m★	*Regular Variable*
n★	*Irregular Variable*
ห★	*Eclipsing Variable*
○	*Open Cluster*
●	*Globular Cluster*
■	*Planetary Nebula*
□	*Bright Diffuse Nebula*
§0	*Elliptical Galaxy*
§S	*Spiral Galaxy*
§ʃ	*Barred Spiral Galaxy*
§#	*Peculiar/Irregular Galaxy*

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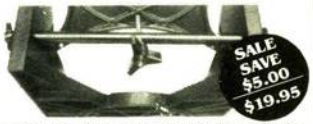

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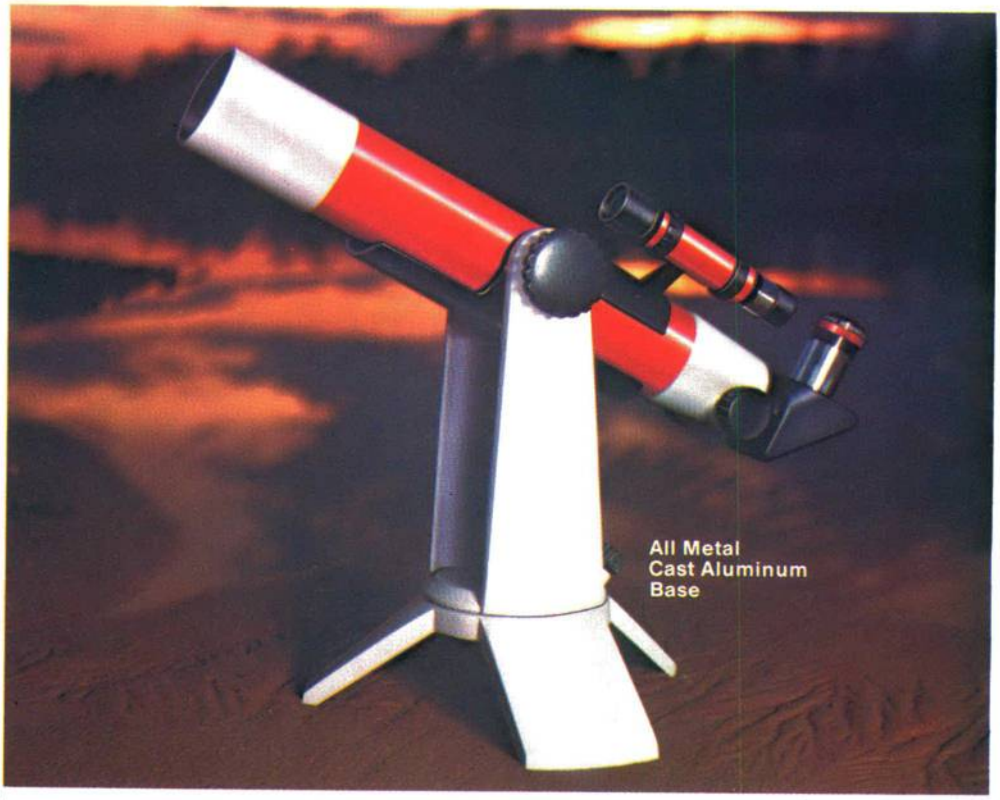

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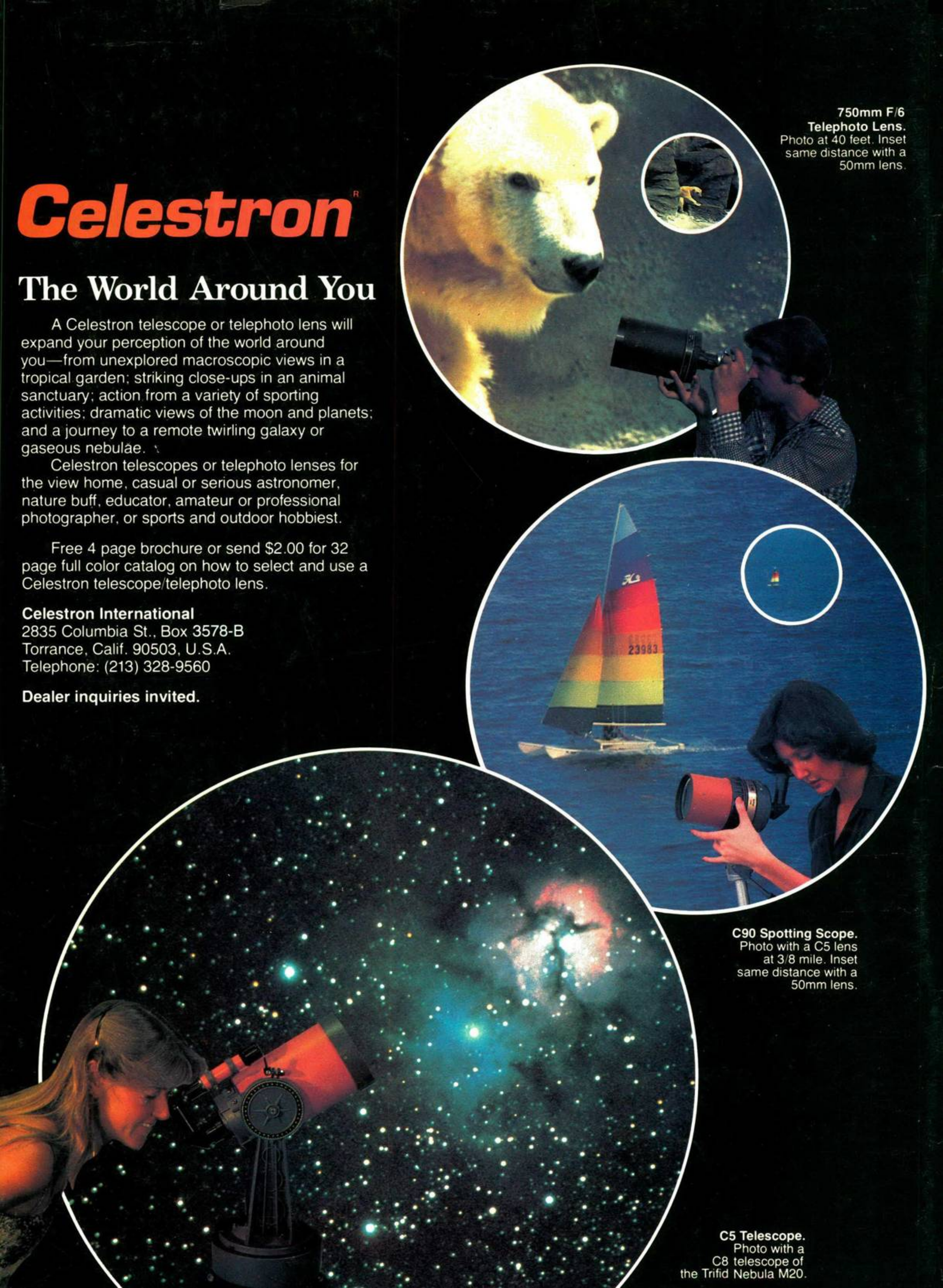

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